

*Department of Energy/
National Science Foundation
Review Committee Report*

for the

Technical, Cost, Schedule, and
Management Review

of the

**DARK ENERGY
SURVEY (DES) PROJECT**

January 2008

EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science (SC) and National Science Foundation (NSF) review of the proposed Dark Energy Survey (DES) project was conducted on January 29-31, 2008 at Fermi National Accelerator Laboratory. The review was conducted at the request of Dr. Dennis Kovar, Associate Director for High Energy Physics, DOE/SC, and Dr. G. Wayne Van Citters, Director, Division of Astronomical Sciences, NSF, and was chaired by Mr. Daniel Lehman, Office of Project Assessment, DOE/SC. For DOE, the purpose of this review was to assess the readiness to establish the technical, cost, and schedule baseline of the Dark Energy Camera (DECam) project in preparation for Critical Decision (CD) 2, Approve Performance Baseline. In addition, the project plans to seek CD-3a, Approve Long Lead Procurement and a limited set of other fabrication activities. For NSF, the review served to assess the progress and status of the proposed Blanco Telescope at the Cerro-Tololo Inter American Observatory (CTIO) facilities improvement project (CFIP) and data management system (DESDM) projects.

The Committee recommended approving CD-2/3a for DECam, the DOE responsibility, pending resolution of the recommendations in their report.

The DES experiment proposes to utilize the existing CTIO in Chile. The construction project includes the new camera, DECam, optimized for the study of dark energy, the CFIP upgrades and a DESDM. The DES is requesting funding for the DECam (from DOE) and funding for the DESDM and CFIP (from NSF). Funding for CFIP would be provided through the National Optical Astronomy Observatory (NOAO), CTIO's parent organization. In addition, funds are being requested from other U.S. and foreign institutions.

The DECam technical design was found to be satisfactory to meet the performance requirements. The procurement and fabrication plans are appropriate and the contingency is adequate. The Committee was concerned about the costs of engineering and integration and recommended they be reviewed to ensure sufficient support and contingency. The project is requesting CD-3a for long-lead time items: Charge-Coupled Devices (CCD) processing and packaging starting in April 2008 and hexapod procurement in October 2008. The Committee recommended a finite element modal analysis to validate the design of the hexapod prior to procurement. They also recommended completion of noise tests and a review of the Aluminum Nitride (AlN) boards for the CCD packaging prior to full production orders.

The DESDM project has made significant progress since the May 2007 DOE/NSF review though there were still areas that are not well-defined. The Committee felt that the staffing plan was very lean and recommended that the Work Breakdown Structure (WBS) and costs be reevaluated. The CFIP technical designs satisfy the performance requirements.

The DECam cost baseline of \$32.9 million is supported by detailed and documented cost and contingency estimates. Increases from the CD-1 (Approve Alternative Selection and Cost Range) estimated Total Project Cost (TPC) of \$25.0 million were due to increased equipment costs (\$1.5 million), incorporation of university engineering labor (\$1.1 million) and incorporation of the R&D starting at CD-0 (\$5.3 million). The MIE has a contingency of \$5.1 million (32 percent). The project requested CD-3a (Long Lead Procurements) at a cost of approximately \$2.1 million. The DECam project presented a funding-constrained schedule based upon a bottoms-up resource-loaded schedule. The schedule contingency for the CD-4 milestone is twelve months, which was deemed to be adequate.

The DESDM team presented a TPC of \$7.6 million using a mix of funding sources. The Committee recommended review of their staffing plan, which may affect costs. The project presented a resource-loaded schedule that follows a series of spiral development cycles and has a schedule contingency of nine months. NSF funding for R&D has already been awarded. The project submitted a \$2.9 million proposal to NSF for three years starting in FY 2009 and a decision will be made by NSF pending completion of the recommendations for reevaluating the costs.

The CFIP project is estimated at \$860K. The team presented a summary schedule with approximately twelve months of schedule contingency, which was deemed to be adequate. The project is expected to be funded out of the CTIO operating budget, contingent upon NSF approval.

ES&H aspects are properly addressed with appropriate hazard analyses and safety documentation completed for this stage of the project.

The project team has most of the tools in place to successfully manage the project. The global Memorandum of Understanding between the collaborating institutions is comprehensive and should be signed as soon as possible.

There were no specific Action Items resulting from the review.

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1. INTRODUCTION

The discovery that the expansion of the universe is accelerating was first announced in 1998. Studying the nature of the “dark energy” causing this has become one of the most important science objectives in physics and astronomy. This mysterious dark energy comprises about 70 percent of the matter-energy contents of the universe. Not much is known about it other than that it exists.

Determining the nature of dark energy is a high priority science objective for the Office of High Energy Physics. The Dark Energy Survey (DES) experiment offers a cost-effective and timely approach to unraveling the mystery of dark energy.

The DES experiment will use the existing Blanco Telescope at the Cerro-Tololo Inter American Observatory (CTIO) in Chile to study the nature of dark energy. The project includes the fabrication of a new camera (DECam) optimized for the study of dark energy, the CTIO facilities improvement project (CFIP) for upgrade to the telescope and CTIO facility, and a data management system (DESDM). The DES project plan calls for funding for the DECam to be provided by the Department of Energy (DOE) and funding for the DESDM and CFIP by the National Science Foundation (NSF). Funding for CFIP would be provided through the National Optical Astronomy Observatory (NOAO), CTIO’s parent organization. In addition, funds are expected to be provided from other U.S. and foreign institutions.

The DES collaboration consists of scientists from Fermi National Accelerator Laboratory (Fermilab), Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), the NOAO, five U.S. universities, and institutions in Brazil, Spain, and the U.K.

In exchange for providing the instrumentation, the DES collaboration will get 30 percent of the Blanco telescope observing time over a five-year period. DES will provide significant science results using all four methods recommended by the Dark Energy Task Force: supernovae, galaxy clusters, baryon acoustic oscillations, and weak lensing. The main method is the use of galaxy clusters. They plan to combine their data with other telescope experiments such as the South Pole Telescope to enhance their results. Their data will improve the figure-of-merit well above the recommended factor for a Stage III experiment.

For DOE, the purpose of this review was to assess the readiness to establish the technical, cost, and schedule baseline of the DECam project in preparation for Critical Decision (CD) 2 approval. In addition, the project plans to seek CD-3a, Approval Long Lead Procurement, and a limited set of other fabrication activities. For NSF, the review served to assess the progress and status of the proposed CFIP and DESDM projects, and to inform the decision about further funding by reviewing a pending proposal.

2. SCIENCE

2.1 Findings

The context of the science case for the DES is presented in the report “Dark Energy Task Force” (2006, astro-ph0609051) commissioned by DOE, NSF, and National Aeronautic Space Administration (NASA). The Dark Energy Task Force (DETF) defined different stages for the studies of dark energy:

- Stage I represents what is now known about dark energy;
- Stage II represents the anticipated state of knowledge upon the completion of ongoing projects that are relevant to dark-energy;
- Stage III comprises near-term, medium cost, currently proposed projects; and
- Stage IV comprises a Large Survey Telescope (LST) and /or the Square Kilometer Array (SKA), and/or a Joint Dark Energy (Space) Mission (JDEM).

In particular, the DETF recommended:

“II. We recommend that the dark energy program have multiple techniques at every stage, at least one of which is a probe sensitive to the growth of cosmological structure in the form of galaxies and clusters of galaxies.”

“III. We recommend that the dark energy program include a combination of techniques from one or more Stage III projects designed to achieve, in combination, at least a factor of three gain over Stage II in the DETF figure of merit, based on critical appraisals of likely statistical and systematic uncertainties.”

“Smaller, faster programs (Stage III) are needed to provide the experience on which the long-term projects can build. These projects can reduce systematic uncertainties that could otherwise impede the larger projects, and at the same time make important advances in our knowledge of dark energy.”

“13. Six types of Stage-III projects have been considered. They include:

- a. A BAO survey on a 4-m class telescope using photo-z’s.*
- b. A BAO survey on an 8-m class telescope employing spectroscopy*
- c. A CL survey on a 4-m class telescope obtaining optical photo-z’s for clusters detected in ground-based SZ surveys.*
- d. A SN survey on a 4-m class telescope using photo-z’s.*
- e. A SN survey on a 4-m class telescope employing spectroscopy from an 8-m class telescope*
- f. A WL survey on a 4-m class telescope using photo-z’s.*

These projects are typically projected by proponents to cost in the range of tens of millions of dollars. (Cost projections were not independently checked by the DETF.”

The DES will survey 5,000 sq-deg in the filters *grizY* and a repeated deep pointing of approximately ten sq-deg for ten percent of the time to find and follow approximately 1000 supernovae in *riz* in the redshift range $0.3 < z < 1$. To do these surveys, the DES will build the DECam, which is a 3 deg-sq camera using fully depleted CCDs. The survey will use the NOAO Blanco 4m telescope at CTIO, using 30 percent of the telescope (525 nights) from 2011-2016. The DECam is scheduled to be delivered to CTIO in December 2010, on the telescope in March 2011 for the first science images, and final handover by April 2012. The rest of the time, the DECam will be made available to the NOAO user community through the usual telescope time allocation process at NOAO.

The DETF report, released in July 2006, recommended that one or more mid-term experiments with a combination of techniques be done, and that (in combination) they should achieve at least a factor of three gain in the DETF figure of merit over current projects.

The DES will measure properties of dark energy using the four probes of dark energy recommended by the DETF—supernovae, galaxy clusters, baryon acoustic oscillations, and weak lensing. The 10-sigma limiting magnitudes along with a two percent photometric error will measure photometric redshifts for individual galaxies to a precision of 0.1 in z , and to 0.02 for galaxy clusters. The DES will select clusters and estimate their mass using weak lensing, Sunyaev-Zel'dovich (SZ) detection from the South Polar Telescope (SPT), and optical galaxy cluster identification. The DES will cover the full SPT field. Using an equation of state formulation of $w(z) = w_0 + w_a(1-a)$, the estimated increase in the figure of merit from the expected Stage II experiments will be 4.6, consistent with the findings of the DETF for Stage III experiments.

The DECam can reach to higher redshifts because the fully depleted CCDs have high quantum efficiency past 1 micron, and produce no fringe patterns. The DES will collaborate with the European Southern Observatory Visible and Infrared Survey Telescope (VISTA) and its VISTA Hemisphere Survey (VHS) that will provide JHK_s photometry of the DES survey region using the VISTA 4m telescope in Chile. This will improve the photo- z 's measurements from a 1σ error of 0.073 to 0.059, assuming 10σ limits of $(g, r, i, z) = (24.6, 24.1, 24.0, 23.9)$, and greatly improve the redshift errors beyond $z \sim 1.3$. Since the May 2007 DOE/NSF review, the DES has signed a Memorandum of Understanding (MOU) with the VISTA project to add JHK photometric data from the VHS to the DES database, in return for access to the DES database.

The photometric redshifts are important for the four tests, and extensive atlases of spectra are needed to train the photometric redshift technique. At present, the DES will include the spectroscopic and photometric catalogs of SDSS equatorial stripe 82, CDF-South, SNLS D1/Virmos VLT, XMM-LSS, and ELIAS S1, to help calibrate these important photometric

redshifts. The SDSS field is particularly important to verify the photometric accuracy required in the Science Requirements Document. It is expected that at the time of the start of the DES there will be roughly 400,000 spectra in the magnitude range covered by the DES from future spectroscopic surveys.

2.2 Comments

The Committee found that the science case for the DES clearly meets the definition of a Stage III mission as described in the DETF report. There are two parts to the Stage III mission, and they have satisfied both: 1) the Figure of Merit based on the four main experiments of the DES, along with certain assumed priors, will achieve an estimated gain of 4.6 in the FoM, well above the factor of three recommended by the DETF, and 2) the project has done an excellent job of anticipating and modeling the known systematic errors in the various aspects of the experiment. Understanding these systematics and controlling them are extremely important for the Stage IV experiments such as the JDEM and the LSST.

The scientific techniques for studying dark energy via the four major science routes as laid out by the DES continues to be of primary importance in the study of dark energy. The DES remains a leader in the Stage III science projects and no other large experiment has been proposed to affect this leadership on the time scale for the completion of the project. It is clear, however, that the instrument must be pursued on a time line as given to the Committee in order for this project to make a large impact in Stage III science.

DES was conservative in developing science requirements in order to match technical constraints, including matching the science to what the telescope can safely deliver. In other words, there continue to be no large looming technical requirements that could compromise the science goals. As stated in the May 2007 DOE/NSF review report, *“the DES maintains a healthy advantage in getting the science done, provided that the funding does not slip.”*

Since the May 2007 DOE/NSF review, the Committee noted significant progress in: formation and co-ordination of science working groups; organizing access routes to the U.S.; a much strengthened supernova science case; inclusion of weather patterns in the modeling of the observations; and a mature science requirements document.

At the time of the CD-1 review, the Committee made a number of recommendations to be considered prior to CD-2 approval. The Committee found that the project has answered and met these recommendations, and summarized their responses and concurred with their conclusions:

1. *Explore a program to improve Blanco telescope image quality from 0.9" to 0.7"
Evaluate such a program in terms of incremental cost to the project, incremental science gains, and the possibility of real improvement in the image quality.*

A goal of median seeing of 0.8" was adopted by the DES, while maintaining the requirement of 0.9".

2. *Convene an NSF, NOAO, and DOE common users advisory group to recommend the U.S. user's community needs for the use of DECam.*

The DES/Ferimlab/NCSA/NOAO MOU created a process whereby NOAO uses its existing advisory committee to examine the community needs. NOAO will canvas the community through the NOAO Users Committee.

3. *Resolve science overlap between DES science goals and user community science goals in the case where the user community proposes for time on DECam to do the DES science.*

The NOAO Time Assignment Committee will receive a yearly report on the scientific status of the DES, which will be considered in the TAC process. The Committee felt that this is the best way to gauge overlap with the DES. The NOAO TAC can then approve projects that are synergistic with the DES goals, or even overlap with the goals if the science is compelling. This will allow free access to scientific inquiry for the U.S. users of NOAO.

4. *Actively review progress of competitors to maintain timeline towards scientific goals.*

The DES maintains contact with competing projects through conferences and informal discussions.

5. *Determine the uniqueness of the science beyond achieving the factor of three goal of Stage III experiments.*

The uniqueness of the DES was laid out in the DES answer to the May 2007 DOE/NSF recommendations, and will not be repeated here.

6. *Consider making the goal of one percent relative photometry as best effort goal with two percent minimum goal.*

The project adopted a goal of photometric accuracy at the one percent level. This is especially important for the supernova science case.

7. *Review and expand the goals of the supernova science component. Consider varying the cadence of data in the wide field survey to maximize sensitivity to SN science.*

The DES has established a new SN working group, and has shown significant progress in revising the SN science case to fit the overall DES observing strategies.

8. *Organize a coordinated theory group across all the science projects.*

It is expected that the Simulations Working Group, which is composed mainly of theorists from the other working groups, will evolve into the theory group.

9. *Create a plan for the DES if the SPT telescope for some reason does not deliver the SZ clusters.*

The SPT project should be completed well before the end of the DES project, allowing for ample time to modify the science goals if there is failure with the SPT. If the SPT for some reason does not deliver the SZ galaxy clusters, much of the science can still be done with a cluster catalog selected from optical+NIR from VHS and DECam observations. The wide-area survey, while originally designed around SZ clusters, is very well suited for weak lensing and large-scale structure (BAO) science.

10. *Produce quantitative goals for the improvement of systematic errors for the Stage IV experiments, as outlined in the DETF.*

These goals are set out in the draft of the new Science Requirements document.

Given the science case presented to the Science Committee members and the answers to the May 2007 DOE/NSF review recommendations, the Committee found that the science case clearly passes the requirements for CD-2 approval.

The Committee provided the following recommendations. These recommendations are of a minor nature and do not have to be resolved prior to CD-2 approval. They should be revisited at the time of CD-3 approval.

2.3 Recommendations

1. Finalize the science requirements document within two months.
2. Convene the Supernova Science Working Group to review the basic science goals of the supernova case. Special attention should be given to utilizing the unique features of the DES. A fully developed supernova science case should be made within six months.
3. Create test observing schedules considering the observing cadences, image quality, and photometric weather goals to plan how the time will be divided between the four science cases. This should be done within six months.
4. Canvas DES partners for other minor science cases to see if they will fit into the DES observing strategies.

5. Consider allowing the detailed nightly observation logs (date, time, filter, exposure time, weather quality, seeing) to be available to the U.S. community in real time for the creation of synergistic science.

3. TECHNICAL

3.1 Dark Energy Camera (DECam)

3.1.1 Optics, Optical Corrector, Mechanical Systems

3.1.1.1 Findings

Work Breakdown Structure (WBS) tasks in the area of optical and opto-mechanical assemblies are complete with resource loading and documented cost estimates.

Six of nine recommendations from the May 2007 DOE/NSF review have been fully addressed. Pending items include a stray light analysis and the design of the C1 lens cover. The two tasks will be contracted to outside engineering groups. Finite element analysis of the combined Dark Energy Camera (DECam)/telescope structure was performed but did not include a modal analysis. This will be completed by the project team.

The DECam project hired a Project Scientist (50 percent FTE), whose principal responsibility is translating DES science requirements into technical requirements. System engineering documents (requirements and interface documents) are being developed and configuration control is being implemented.

The procedures for manufacturing the DECam barrel assembly are adequate. The process relies on controlling the buildup of tolerances to ensure that optical components are aligned with sufficient accuracy. The spacing of optical components will be adjusted during assembly of the DECam barrel using machined spacers to optimize for variations in the as-built lenses from nominal. An end-to-end optical test is not planned.

After a review of different types of mechanisms, the project elected to use a hexapod for controlling DECam position within the cage assembly. The decision is based on a review of requirements that concluded five-axis motion is required to maintain the optical alignment of DECam relative to the telescope primary mirror in the presence of gravity and thermal deflections of the telescope structure. The project has received engineering and fabrication cost estimates from a number of vendors. Hexapod development and procurement is near the critical path. The project is preparing to issue a request-for-quotes for an engineering study leading to fabrication and is requesting CD-3a approval to go forward with this long lead-time assembly.

Glass blanks have been received for the C1-C5 lenses that comprise the imaging system of DECam. The University College of London has responsibility for managing the polishing and coating of the lenses and for mounting the lenses in cells and final installation and alignment of the optics in the barrel assembly. This critical work is being performed as an in-kind contribution. The lenses will be polished and coated by a commercial vendor. Quotes have been obtained from optical fabricators and UCL is preparing to move forward with the polishing pending final approval from its funding agency.

The filter changer and shutter assemblies are being provided by University of Michigan. The assemblies are based on scaling up of existing designs. The technical and schedule risk for these items is deemed to be low.

The DECam interference filters are larger than any previous filters of this type. Filter vendors have thus far been unwilling to commit to the tight specifications for uniformity established by the project. The project is still discussing this with the vendors but it is likely the filter specs will have to be relaxed. While this may complicate the data reduction, it is not expected to compromise the science but this should be discussed with the DESDM project.

The procurement of filters is on the critical path due to funding restrictions. No spares are currently planned.

At the time of CD-1 the top ring and cage assembly were rotated in the telescope on a trunion to switch between DECam and f8 operation. This mechanism was eliminated in the current design. The f8 secondary mirror will be attached to the lower end of the DECam cage assembly and the mirror will be removed from the telescope when the DECam is in use. Removable counterweights will be used to maintain the telescope balance. A changer mechanism (“f8 Manipulator”) will be provided to move the secondary mirror into position for insertion and removal. This change opens up space behind the camera assembly.

Project thermal specifications allow the DECam structure to vary by up to 2°C from ambient. A shroud around the barrel assembly traps excess heat, which is removed by a cooling system.

3.1.1.2 Comments

Cost estimates appear to be conservative for the most part. Contingency allowances on equipment and labor are based on established procedures that take risk into account.

Regularly spaced milestones plus other metrics are sufficient for tracking progress. Slack is not explicitly included in the WBS. No schedule problems were identified at the time of the review; however, the time and expense allowed for assembly and integration of the DECam on the telescope simulator at Fermilab and on site at CTIO appear optimistic and should be thoroughly reviewed prior to CD-2 baselining of the budget.

System engineering improved within the DECam project with the hiring of a project scientist. Still, it is not clear how system engineering is coordinated within the overall DES project. The Committee judged that the document tree representing the traceability of requirements, both forward (top-down) and backward (bottom-up), lags the overall technical development of the project. While the design appears sound, at no time during the review was an error tree or error budget presented to substantiate the technical design, hence budget and schedule. The Committee urged that this step be completed as soon as possible.

A FE modal analysis of DECam assembly mounted in the telescope top ring is needed to validate the design of the cage, vanes, and hexapod. The analysis will provide the basis for specifying stiffness requirements for the hexapod assembly. It may also reveal problems in the cage/vane design that lower modal performance that should be addressed before final design. Specifically, the subcommittee for opto-mechanical systems noted that the load path between the DECam through the hexapod to the support vanes was not as direct as an optimal path. The analysis should be completed prior to the hexapod being approved for CD-3a. The results of this analysis should be incorporated into the overall image quality error budget. The Committee noted that the current assignment of zero contribution from wind buffeting (“assuming a calm night”) to the image budget is not realistic given the site wind statistics at CTIO.

A cage temperature of 2°C above ambient is likely to produce significant degradation in image quality (cf. Zago, 1995). It is difficult to assess the true impact of this without a comprehensive image error budget and analysis but the thermal design should be reviewed in light of this effect.

Time did not permit an adequate discussion of the proposed f8 Manipulator concept. The Manipulator rises roughly 14 feet above the floor and passes through telescope structure. Personnel engaged in the mirror removal will ride up and down on platforms attached to the lift. The Committee had some questions regarding operational aspects and safety of the proposed concept. Potential hazards include collision with the telescope and other structure, pinch points, large seismic loads and failure of the mechanism with people on board. A review of the concept with a discussion of safety issues in coordination with the CTIO staff is warranted.

The control path for the hexapod is not well defined. This starts with the analysis of wavefront measurements taken in the focal plane and the translation of those measurements into corrective motions of the DECam cage. Active figure control of the primary mirror is also an option if the wavefront sensing is sufficiently accurate. Such techniques are used on the Magellan and LBT telescopes and most new telescopes now in planning. Well-established numerical methods can be applied to invert the wavefront error matrix to corrective actions needed to maintain alignment and figure control. A review of these methods is warranted given the stringent requirements on image quality and shape imposed by the weak lensing science case. The exact method of determining the corrective actions will affect the requirements for wavefront sensing, thus will influence the design of the F&G CCDs in the camera.

Advancing the procurement schedule for the interference filters by one year would reduce schedule risk. The lack of spares in the event a filter is broken will have a direct impact on the science that can be done until a replacement is obtained. Filters are particularly susceptible to damage due to their fragility and the frequency with which they are handled during operations. The DECam project should evaluate the programmatic impact of the loss of a filter and obtain a quote for the cost of providing spares. Filters purchased in pairs should have lower unit costs and better matching characteristics.

3.1.1.3 Recommendations

1. Continue to implement the systems engineering controls and documentation prior to CD-3b.
2. Complete the pending recommendations from the May review prior to CD-3b.
3. Review the costs for DECam assembly and integration at Fermilab and CTIO and provide a generous contingency to the budget and schedule for these activities prior to CD-2 budget baselining.
4. Perform an FE modal analysis of DECam in the telescope upper structure. Use the results of the analysis to confirm the stiffness of the hexapod/cage/vane assembly and set specifications for the required hexapod stiffness. Incorporate those specifications in the request-for-quotes being sent to potential hexapod vendors.
5. Analyze the effect on image quality of a hot air plume caused by the cage assembly at 2°C above ambient prior to CD-3b.

6. Investigate the cost to provide a set of spare filters prior to CD-3b.
7. Develop a deterministic strategy to control the hexapod positioner in the required five degrees of freedom prior to CD-3b.
8. Proceed to CD-2 with opto-mechanical systems.
9. Proceed with CD-3a procurement of the hexapod assembly pending the successful completion of the hexapod engineering study demonstrating the proposed design complies with project specifications.

3.1.2 Charged-Coupled Devices (CCD) Focal Plane and Camera

3.1.2.1 Findings and Comments

CCD Manufacturing

CCD fabrication is progressing well at DALSA and LBNL, with fabrication rate being limited by the funding profile.

The packaging of the CCDs at Fermilab is now a mature process with good results (e.g., CCD height and flatness) and minimal impact on yield.

Overall yield is acceptable (26 percent) and now known to a fidelity, which is appropriate to this stage of the project; however, it is commonplace in low volume production to experience major yield loss that cannot be predicted from the sample size available to make yield estimates. For example, the fabrication at LBNL is conducted on (sometimes old) machines for which there are no spares so that a single process failure could cause either multiple CCD losses or long delays.

CCD Testing

Previous recommendations for improving the test hardware and software were followed. The testing program is in good shape, providing comprehensive and accurate measurement capability, automated operation, and adequate safety margin for throughput. The Committee applauded the use of database tools to store and collate test data, allowing, for example, histograms of a given performance parameter across all or a selected set of devices to be plotted. Keep up the good work.

Focal Plane Assembly

A well-planned scheme was presented for safe installation of CCDs on (and attachment to) the focal plane support plate, which protects the CCDs, will produce a flat focal surface and relieve stresses due to differential contraction between the Invar CCD package and the Aluminum support plate. Thermal FEA was presented that predicts a slight bow of the focal plate (approximately 10 μ m) due to thermal gradients.

Dewar and Vacuum System

The internal volume and surface area of DECam is not exceptionally large for an astronomical instrument. The unusual feature is the large amount of Kapton, which will outgas water vapor.

An ion pump was selected as the preferred alternative on the basis that getters present reliability/maintenance issues. The ion pump requires electronics, which will not work in a power outage and will glow while operating.

Water vapor, which will account for the pressure in the dewar will rapidly freeze out at start of cooling and thus does not affect vacuum performance. It is important to remove this water, nonetheless, since it can cryopump onto the detectors when the cooling system is turned off if the detectors warm more slowly than the surfaces onto which the water has frozen.

The majority of astronomical CCD systems use getters, and do so successfully. The reports that getters present operational problems are probably based on examples of operator error.

While zeolite will indeed lose some pumping ability after adsorbing water vapor its capacity for water adsorption is enormous, and is generally only seriously degraded when the zeolite is exposed to atmosphere for many hours. A vacuum hatch should be provided for easy access to the zeolite container, and the dewar should be backfilled with dry gas prior to being opened.

The activated carbon getter regenerates at room temperature so that optimum pumping of air is assured. When used in combination with carbon, the role of the zeolite is to remove water vapor from the vacuum when the dewar is warm and valved off and not to remove gases when cold (though it will generally also do this) so the combination is very reliable.

Since the zeolite will rid the dewar of water vapor when warm and valved-off, the need for long pumping times, and/or large diameter valves and pumping lines is alleviated.

The principal challenge with getters is to provide fine enough mesh on the container to prevent particles from escaping, however this has been done successfully.

The four-inch gate valve with a large diameter hose to an on-instrument turbo pump is a magnificent but is an unnecessarily fast pumping arrangement. Water vapor can be more effectively removed by bleeding a small amount of dry air into the vacuum either continuously or intermittently during initial pump down, and can be further accelerated by heating the dewar walls. Once the bulk of the water vapor has been pumped, the dewar can be valved off leaving the zeolite to adsorb any residual water vapor.

The zeolite will not be saturated in this process, but to play it safe, it can be replaced with new/regenerated material (after a dry-air backfill) once the dewar has been thoroughly “dried out”. Aside from one sieve change (if any) no maintenance should be needed for a year or more.

Cooling System

The constraint on the dewar size (and thus the cooling system) imposed by the mounting of the f8 secondary behind DECam has been removed: the f8 will be mounted in front of DECam when in use instead of performing a top end flip.

The Committee agreed with the project team and with the internal review conducted in December 2007 that the proposed cooling system (which recirculates liquid and gaseous Nitrogen) is technical feasible, and also agreed on the analysis of the thermal load. The Committee differed in assessing the size of the thermal margin required and whether the detector heater power is part of that margin.

The budget appears to be adequate to implement the proposed cooling system. If the function of this review is only to assess whether the cost of the proposed solution is realistic, and not to seek cheaper alternatives meeting specifications, then the following must be taken as *comments* rather than *recommendations*. There appear to be at least three technically feasible ways to implement the cooling system:

1. **Recirculating Nitrogen from a refrigerator off telescope.** This will be the most expensive solution and presents some questions regarding vibration caused by turbulent flow (as noted by the December 2007 internal review), resulting in a need to allocate further funds to a prototype. Some of these costs have already been expended and the instrument design is based on the assumption this will be the solution adopted.

2. **Parallel JT coolers with gas compressors off telescope.** Based on experience from other groups and its own analysis, the Committee judged that by connecting several Joule-Thomson (JT) coolers in parallel a vibration free, reliable cooling system with relatively low operating cost could be constructed at significantly lower implementation cost, while maintaining adequate power margin. Whether three or four 30 W coolers (e.g., standard Polycold Compact Cryocooler with PT30 gas) are required depends on the operating margin desired and whether or not an LN2 precool loop is used to hasten cool down.

The Committee noted that the internal review of the cooling system conducted in September 2007 primarily addressed the technical feasibility of the proposed recirculating Nitrogen system, and did not comment on cost effectiveness. However one of the three bullets in the executive summary echoed comments from the May 2007 DOE/NSF review by stating: “*Consider options which would avoid the use of two-phase flow, such as a subcooled LN2 loop **or JT cryocoolers.***”

The project responded that no JT cryocoolers with sufficient capacity are available, apparently without considering the use of several in parallel.

The preamplifiers inside the dewar dissipate 28W, which was treated as a flow into the cooling system, but presumably this heat could be conducted to ambient instead of being strongly coupled to the focal plane, since the Kapton cables are designed to provide the thermal isolation. The project estimated the maximum heat load to be 113W. By diversion of the electronic power dissipation, that load could be reduced to 85W and by treating the peak detector heater power as “safety margin” one can argue that three Polycold coolers sinking 30W at a head temperature of 133K will be sufficient. The system could be designed so that a fourth head could be installed, if required, while still providing a significantly lower cost solution.

The Committee noted that inclusion of a precool loop would not only reduce cooling time but would also ensure that the JT coolers rapidly reach peak cooling capacity.

3. **Conventional in situ LN2 tank.** With the decision not to mount the f8 secondary behind DECam and perform top end flips, there is ample space to allow a conventional Nitrogen tank. Assuming this is filled once per day to 65 percent capacity (due to the inclination at the prime focus access station) and that a radiation shield cooled by boiloff gas also cools the electronics in the vacuum, then about

46 liters of liquid nitrogen would be consumed per day and tank height would be about 14 inches. This would be by far the cheapest solution in terms of capital cost but would require CTIO to fund an additional \$14K per annum for the liquid Nitrogen (assuming instrument is always cold) above the cost of electricity for the current solution, plus the labor to fill once per day.

3.1.2.2 Recommendations

1. Advance the CCD fabrication work at DALSA/LBNL by earlier procurement of lots. This action would not increase costs, but would change the fiscal years in which the CCD wafers are procured. Specifically: a) procurement of 15 wafers should be advanced from October 2008 to May 2008, resulting in a shift of \$315K, and b) procurement of ten wafers should be advanced from October 2009 to February 2009, resulting in a shift of \$210K.

These early actions will serve to retire risk on the CCDs, and thereby provide a total of five months additional schedule slack. Money will almost certainly be saved through efficiency and yield increases obtained by fully engaging the production facilities while they are functioning smoothly.

2. The Committee recommended CD-3a support for WBS 1.2.
3. Make all 2Kx2K CCDs the same thickness so that they will be interchangeable; adjust heights of focus CCDs by machining the support plate.
4. Since the DECam CCDs are significantly affected by cosmic rays, evaluate a sample of glass from the C5 melt for potential Potassium-40 contamination by placing it in front of a DECam CCD and monitoring the change in CR event rate. Similarly evaluate a sample of the fiberglass used to make the Vacuum Interface Board for potential radioactivity. If Beryllium is used (e.g., alloyed with copper) then test this for radioactivity too.
5. Plan for profilometry of the whole focal plane when cold though a flat window; calibrate against a reference flat. The project scientist should make sure that those working on the PSF fitting for Weak Lensing are shown the data so that they are fully aware of the focus variations on all spatial scales, both within and between CCDs.

6. Incorporate a small auxiliary valve for slowly bleeding dry air into the vacuum during initial pump down to promote outgassing and transport of water vapor.
7. Consider how to heat the dewar exterior during initial pump down to speed up outgassing, though not enough to endanger the dewar contents or seals.
8. Use of a combination of accessible zeolite getter *and* an activated carbon getter (which may be inaccessible) in place of the ion pump.
9. If the ion pump is retained, it is recommend that the team directly measure the optical light emitted by it (in photons/s) inside the vacuum housing, and then trace the anticipated flux from multiple scattering paths that might allow these pump-produced photons to reach the CCD focal plane as stray light. (If a convincing case can be made that the multi CCD test dewar is a worst case scenario, then an empirical test in the multi CCD test dewar may prove more cost effective than scattered light analysis.)

3.1.3 SISPI and Front End Electronics

3.1.3.1 Findings

The Committee was very impressed by the work of the SISPI and Front End Electronics (FEE) teams. These teams are comprised of people with extensive experience on similar projects for the particle physics community. They have successfully carried this experience over to this astronomical work while taking advantage wherever possible of existing tools and hardware in the astronomy community.

FEE Electronics

- All issues raised at the May 2007 DOE/NSF review have been addressed.
- The design satisfies the technical performance requirements.
- The budget for the FEE project is adequate with the exception of integration engineering in FY 2010 and FY 2011.
- The 31 percent contingency for the FEE project looks appropriate given that they are building upon an existing design.
- ALN CD-3a—there is further testing required before proceeding with the purchase.

SISPI

- Has a well-formulated plan with a believable fully resource-loaded schedule.
- It builds on existing software used at CTIO and by NOAO.
- Most of the associated hardware are commodity items with well understood costs.

- As such, the contingency of 22 percent is adequate.
- SISPI is largely a university based software project conducted by physicists. It is highly dependent upon base program support. This represents a substantial risk that was identified by the Level 2 managers.

3.1.3.2 Comments

May 2007 DOE/NSF Review Issues

Project responses to the May 2007 DOE/NSF review recommendations are shown below (in italics). They showed detailed discussion of the tests and trade offs involved in making these decisions. The Committee was satisfied that they made the correct decisions. They showed both PSpice simulations and test bench results to confirm their choices. For example, the project chose the AD 8065 preamp, which was vetted by NASA for extreme temperatures. A detailed discussion of all these choices was given in their presentations.

Down-select, before CD-2, the configurations of electronics modules with justification for each option chosen. Experimental results should be compared with theoretical expectations.

JFET on or off AlN substrate. They elected to keep the JFET off the AlN substrate. There is no performance advantage to keeping it on the AlN substrate vs. the CCD Interface board. It simplifies the AlN board design and allows them to repair JFETs in event of a failure.

Paralleling JFET's versus having a preamplifier board. The CCD Interface Board was designed for parallel JFETs, but allows for operation of either single or parallel JFETs. Initial testing shows they require a preamplifier board with either a single or parallel JFET configuration.

Preamplifier in or out of dewar (if applicable). Preamplifier will be located inside the dewar. There is no convenient location for the preamps on the outside of the dewar.

Single-ended or differential signal transmission. Single-ended signal transmission is final plan. This works well and has met the readout specifications.

Kapton versus micro-coax cable. They are currently still testing various options.

Mechanical design choices of connector attachment to CCD package. They are switching from the Nanonics connector to an Airborn 37-pin nanominiature connector on the CCD package based on the recommendation of LBNL. LBNL has had good results with this connector and found better availability. This will be tested with the present AlN substrate.

Power supply configuration choices. A Vicor Switching Power Supply with a custom filter box will be used in the FE Electronics crate. This gives performance equal to the linear supplies currently used in the teststand.

Multi-crate synchronization choices. Synchronizations will be done in FPGA logic. This will allow a span an expanded range of synchronization window.

Consider, as an option, calling an external review of the video signal chain prior to CD-2. An internal review appeared to be extensive and resulted in some useful design improvements. For example, the ground structure of the Kapton cable was improved.

Analyze scenarios that could put CCDs at risk and evaluate mitigation strategies, if applicable (e.g., power-on or off, or software initialization transients exceeding safe voltage limits). They presented a detailed analysis of all the possibilities found by their study, including mitigating designs such as clamping diodes. Details are available in their presentations.

List and review all material properties for vacuum compatibility (e.g., outgassing). A detailed table of all materials and their outgassing rates was shown and did not appear to be a cause for concern.

Ensure that a failure in one CCD string does not impact the operation of other CCDs. There is a worst case scenario where failure of one CCD could impact the readout of a second. Unfortunately, due to the density of buffers required on the boards it is not possible to completely eliminate this possibility.

Evaluate tracking errors caused by the unavailability of guiding information immediately prior to the exposure and resulting from persistence effects in the guide CCDs. An extensive discussion of this was presented showing a significant difference in signal strength between guide stars and persistent images in worst case scenarios. This should not be a problem.

Other Comments

It is important to note that the front-end electronics design builds upon the existing NOAO design. The team has run tests with the Monsoon 1 system that shows that it is close to meeting the needs of the DECam. Modifications to the design are needed to change the form factor to allow the boards to be used in the physical constraints imposed by the DECam. Also some components on the earlier boards are obsolete. Finally, the choice of SLink allows them to leverage existing work from the particle physics community. The choice of Monsoon allows the

use of much existing firmware and software available from NOAO. This allowed them to keep costs well under control and to mitigate risk factors. These choices mean that an overall contingency of 31 percent is appropriate given the extensive use of existing designs wherever possible and the successful operation of prototype systems.

A detailed breakdown of the system integration testing schedule was given. There appears to be sufficient time allocated to debug the system at Fermilab. There may be a need for additional engineering for the final integration at Fermilab and CTIO. Analysis of this was complicated by the fact that engineering resources for this are under the management and focal plane detector WBS items. Combining EE tasks in WBS Items 1.1, 1.2 and 1.3 shows FY 2007–3.9 FTEs; FY 2008–4.4 FTEs; FY 2009–3.7 FTEs; FY 2010–1.2 FTEs; FY 2011–1.4 FTEs. The FY 2010 and FY 2011 engineering FTEs seem on the low side.

The 34 percent overall contingency for Front End Electronics (33 percent for R&D/ 36 percent for production) appears to be adequate given that the present prototypes meet requirements with the addition of some PCB patches that will be fixed with the next iteration. Much of the production is an in-kind contribution from Spain and therefore carries no project contingency.

The decision was made to change the connector on the CCD package from the Nanonics connector being used to an Airborn 37-pin nanominaiture connector based on the recommendation of LBNL. This seems reasonable given LBNL's good experience with the Airborn connector and the difficulties with availability experienced with the Nanonics connector. The plan is to try the Airborn connector on three or four units of the existing v1.0 AlN substrate. After successful results of that test, the AlN layout will be modified (v2.1) to better accommodate the Airborn connector. About 20 units will then be fabricated and tested. Successful completion and satisfactory test results from this small quantity run will demonstrate readiness for production. A production readiness review at this stage would be appropriate.

For each board type, they produce twice as many as needed in the final system and keep the remaining as spares. Thus there are 100 percent spares planned for each PCB and crate, including the small boards to be mounted inside the dewar and the Kapton cable. Given that all of the boards have multiple copies in the system, this should be quite adequate for swapping out any boards that fail, i.e., there are multiple spare copies of each board. Assuming that any failed boards will need to be repaired to keep the whole system operational for up to ten years, an analysis of which components are most prone to failure and that are likely to become obsolete should be conducted and an appropriate number of these component spares should be purchased. Presumably, this would become part of the in-kind contribution from Spain along with the production boards.

A detailed presentation was made of the grounding scheme planned for the DECam. This involves not only the electronics but all the conducting objects that make up the telescope. The engineer responsible for this work understands the issues and appears to have a good plan for eliminating ground loops and noise from unwanted stray currents. There are several aspects of the existing telescope construction that are not well understood. Therefore, it is imperative that a planned trip to CTIO be completed very soon so that a complete plan can be formulated and to minimize surprises during installation.

The SISPI project has a well-formulated plan with a believable fully resource-loaded schedule. Since it builds on existing software used at CTIO and by NOAO and most of the associated hardware are commodity items with published prices, the overall 22 percent contingency seems adequate. The purchase of hardware (mostly computers, storage devices, and network gear) carries an appropriate 20 percent contingency, 10 percent for software licenses, 40 percent for the Cloud Camera, and 30 percent for Fermilab software development. (Note that there was a clerical error in the contingency numbers originally presented for 1.6.1, leaving out roughly \$28K for two items. This will be corrected.)

Most of the SISPI software development is a university based project conducted by physicists. This represents a substantial risk to the project if the university base research program cannot be maintained. Also, there is no contingency included for this base program work. Any overrun will have to be covered by scope reduction. This is understood by the Level 2 managers.

Travel for the Fermilab engineers (primarily for the front-end electronics) is lumped together in the management section (WBS 1.1). It appears to be adequate but it is difficult to determine exactly how much is planned for the front-end electronics and the SISPI. Likewise, travel for all the university personnel working on SISPI must be covered by base program funds. It would be very prudent at this time to make a detailed estimate of how much travel will be needed for both projects so that this can be cross-checked against expected funding from the project and from the base program.

The SISPI resource-loaded schedule, including university personnel, appears quite reasonable, however, software projects have a history of slipping. To avoid any unexpected delays, it would be very prudent to monitor the SISPI progress closely and modify the resource-loaded schedule as the real rate of software development becomes better understood.

3.1.3.3 Recommendations

1. Recommend CD-3a approval of AIN production contingent upon the planned tests being completed and approved prior to the actual start of production.
2. Identify the components that are most prone to failure and which components are likely to become obsolete and use this information to determine the appropriate number of component spares.
3. The MOU with Spain should specify the number of component spares.
4. Modify the plan to include additional FEE engineering resources in FY 2010 and FY 2011 for testing and integration.
5. Schedule a trip, to be taken within six months, by the Power and Grounding engineer, to CTIO to work with relevant CTIO engineers and transfer knowledge about telescope grounding and local power conditions.
6. Monitor SISPI progress closely and modify the resource-loaded schedule as the real rate of software development becomes better understood.
7. Make a detailed estimate of travel required to complete the project at CTIO. This estimate should clearly identify the travel that will be funded from the project and the travel that should be funded by the base program.

3.2 DES Data Management (DESDM) and DECam Simulations

3.2.1 Findings

The DES Data Management (DESDM) project has made significant progress since the May 2007 DOE/NSF review, and has answered a number of the review recommendations. In particular, the project prepared requirement documents, included some of the pipelines needed for DES science in the requirements and WBS, worked to strengthen the group working on the core astronomical algorithms, and made good progress in defining the Community Pipeline.

The simulation effort has proven its value to the project, providing the inputs to the project's data challenges. The enhancements needed to develop and validate the algorithms are understood by both the DESDM and simulation teams (examples are the need for more realistic galaxies, and modelling of the effects of optical misalignment on the delivered PSF).

The third Data Challenge (DC3), begun in October 2007 and completed on schedule in January 2008, processed about 2.6TB of data, and demonstrated DESDM's ability to integrate a significant amount of software into a working pipeline. The scope of the challenge, taking raw data and populating a database with the derived catalogues was appropriate. The pipeline made extensive use of trusted astronomy legacy codes such as SWARP and SExtractor, developed by team member Bertin.

The DC3 processing exposed a number of problems in the software stack and computational infrastructure such that it took one month to process ten nights of data.

Timing successful jobs indicated that their standard processing currently takes about ten CPU-minutes per exposure, although this excluded preparing and ingesting catalogs into the database. To understand the time requirements of nightly processing, the Committee relied on the Figure 9-1 of the draft DC3 report (v2) showing processing times. Since the concurrency of the analysis was unclear the Committee had some difficulty in matching these processing times to the statement in Section 9 of the report that the total time to process a night of data was six hours and ten minutes, excluding catalog ingestion; in the future, such numbers should be reported in the more appropriate units of CPU-hours. The team acknowledges that in practice more complex and time-consuming algorithms will probably be required; indeed, some were prototyped during DC3. The DC3 report also states that data ingestion is sped up by a factor of three or four by using a "load and merge" technique. It would be useful to provide a more complete and detailed summary of processing times and concurrencies in future reports, including all steps, and the number of exposures and CCD images processed per night to get a better understanding of the nightly processing duration.

The staffing plan is extremely success oriented; this is reflected in the estimates of the effort required. The DESDM team describes itself as *lean*; the Committee was concerned that it is too lean. There is significant risk that the project cannot be successfully completed with the currently allocated (or proposed for) effort.

The DESDM development plan, notably in the area of astronomy codes, depends critically on contributions from specific individuals, with resulting significant schedule risk. If problems occur, the Committee judged that the current team will be forced to serialise solving them due to multiple single point failures. The project has made hires to provide some backup.

However, the Committee suspected that there were several areas of expertise and responsibility residing with single team members. The Committee further noted that DESDM has several members who provided less than 50 percent of their time, as little as 25 percent of their

time, to the project. While it appeared that all team members are making real contributions to the project, relying on minor fractions of people's time can be problematic. In addition, the team includes two unspecified undergraduate students. All of these issues contribute to our conclusion that the team is understaffed. DESDM appears to lack written plans and/or processes detailing:

- Software engineering (requirements at the level that can be coded to; a clear development plan; unit- and regression-tests; bug tracking; versioning beyond the use of SVN; the build and release plans; and code and application documentation)
- Error budgets, flowed down from the science requirements
- Risk management
- Database specifications, especially for science use

The quality assurance/quality control (QA/QC) process is not well defined, notwithstanding its successful introduction into DC3. Notably, the delineation between what QA/QC is done within the astronomy codes (and simply captured by the QA framework and reported), and what is done by the framework itself, is poorly defined. The Committee further noted that the QC portal functions presented by da Costa had some data discovery functions that would be quite useful for science users of the DES data.

The Committee was pleased that the weak lensing and difference imaging (needed for SNe) codes required by some of the science cases were presented and are partially supported by DESDM. The Committee did not conduct a detailed review of the functionality present in these codes, but noted that the individuals responsible have a strong track record in these areas.

3.2.2 Comments

Acceptance testing of DESDM is currently planned at the system level at the end of the development phase, after the completion of all the Data Challenges. Phased lower level acceptance testing against individual requirements, partnered with regression testing, will help to retire risk during the development phase. It is useful during the development phase to verify that clearly specified requirements are being met by functional elements such as code modules, and to re-verify those requirements are met by later releases of the code modules.

Nightly processing needs have been the major driver to date of the DESDM design. More emphasis should be given to large-scale reprocessing of data in driving the design of the database and pipeline technology. The Committee saw no signs of problems in the current design, but are concerned that operations such as database ingest may not scale well.

In DC3, five to ten percent of submitted processing jobs failed. It was not clear that the causes of the failures were known. The draft DC3 report mentions crashes of the PSM module that go away when run a second time. DC3 did not include non-nominal data (e.g., partial/corrupted readouts). Future Data Challenges should include such data to test robustness of the processing systems, as well as the response of the processing algorithms to pathological data (e.g., first magnitude stars).

Scaling from nightly processing to annual reprocessing and multi-year processing for final catalog production is likely significantly to exacerbate problems with the middleware.

The simulated datasets in DC3 do not include all “real world” instrumental effects (e.g. residual non-planarity of the focal plane, other camera and/or telescope error contributions; a turbulent atmosphere). The Committee would have liked to see system-level, roll-up of error contributions from camera, telescope, focal plane, electronics and data reduction to demonstrate that required science performance (astrometric and photometric) will be met. Such a system-level analysis of performance should be done in conjunction with the other DES program elements at the program management level.

The Committee was concerned that the input catalogues for the simulations did not go deep enough to properly represent the astronomical noise expected in real images.

The data challenges are carried out on a one-year cycle. While this may be appropriate for tests at this level, it does not amount to a modern spiral development pattern. The Committee anticipated that code releases would be made more frequently than once per year, which would drive the need for unit and regression tests at the time of the code releases.

The requirements for the database, either in terms of its availability or functionality, were not clear. Does it need to be up 24/7/365.24? What sorts of index will be required to deliver acceptable performance on what class of query?

The Committee noted that the database carries out two different functions (running the survey and serving up science to the collaboration and possibly the wider community). It is not clear that both aspects can be simultaneously optimised.

The DB will be read-only, but the project should consider providing space for users to generate temporary tables (analogous to the SDSS’ mydb).

Some concern was expressed that the DESDM project assumes that they will be able to interact with a database from the worker nodes of the HPC clusters that will be deployed in five years' time. It is not clear how the objects detected in the nightly processing (and difference imaging) will be assembled into astronomical sources; this is a tricky problem in the presence of variable seeing and deblending.

There is significant commonality between web portals for DES science archive access, the QC access portal, and the described NOAO DPP archive portal. The project should guard against significant reproduction of code with common requirements in this respect, and should seriously investigate a single tool for access to DES, QA, and NOAO (Community Pipeline) archival data, in collaboration with NOAO DPP.

The QC presentation showed eight FTEs dedicated to this task, a seeming mismatch with the overall DESDM budget, given the scope of that portion of the project. The Committee understood that this effort is outside the direct control of the DESDM, which assesses a significantly smaller level of effort. Nonetheless, perhaps there is scope for further integration and task sharing by the QC team with the rest of the DESDM effort. For example, further exploiting the web portal development done by the QC team to satisfy other web portal needs.

The DES program is a pathfinder (along with the one degree imager (ODI)) for implementing an instrument-specific community pipeline generating catalogs for the NOAO E2E system. As a pathfinder, it may require more than 14 FTE-months of effort and an appropriate contingency should be assigned.

The Committee did not understand why real data was thought to be harder to reduce than simulated data.

Mohr stated that the science images would be remapped prior to difference imaging. The Committee judged that this should be reconsidered as it results in correlated noise (and problems if the data is for some reason undersampled).

3.2.3 Recommendations

1. Perform a self-assessment of resource margins and redundancies required to achieve DESDM critical functions, to identify principal risks (in a severity/likelihood matrix). A risk monitoring and mitigation plan should be developed and implemented.
2. Make a concerted effort to recruit more staff, using the risk assessment to identify areas of concern (e.g., astronomy codes, databases).

3. Implement standard software-engineering practices, including developing unit-level test requirements for software elements; unit-level regression testing of software elements; a bug-tracking system for the DESDM systems; and a common code version, build, and release system (including the contributed effort from all partners).
4. Develop a detailed characterization of the computational complexity of the time-critical nightly processing steps, including their floating-point operation counts and their efficiencies and memory, disk and bandwidth loads on target architectures.
5. Develop contingency plans and resource margins for inevitable infrastructure failures.
6. Investigate the potential for shared development of the DESDM QC web portal with the DESDM user/archive portal and NOAO DPP Archive portal.

3.3 CTIO Facilities Improvement Project (CFIP) and Integration

3.3.1 Findings

The CTIO Facilities Improvement Project (CFIP) consists of five separate improvement projects for the Blanco four-meter telescope in preparation for the arrival of DECam. These are all projects that CTIO would be carrying out anyways, but the timing is to some extent driven by DECam and the DES. The budget for these projects is part of the CTIO base budget and does not represent a separate allocation.

The largest and most critical of these projects for the DES is the TCS upgrade project; this is critical for the DES because the existing TCS cannot drive the telescope at a rate sufficient for the DES cadence.

This first project is underway—about 90 percent of the hardware costs have already been incurred. The software and electrical engineering team developed is sufficient for the task as they have experience from the SOAR TCS. The schedule path is good, with detailed milestones densely distributed. The target completion date is roughly 12 months prior to DECam’s arrival at the telescope, which appears to be sufficient contingency.

The TCS timeline has implications for the DECam project; by mid-2009 the exact DECam command interface to the TCS will be fixed; therefore the TCS project needs to be nearly complete by then.

The second project is a replacement of the primary mirror radial supports. This project is well underway. The parts have been ordered, and, although the machining of the supports have long lead times, the project appears to be well-positioned to be completed by June 2009—more than one year before the DECam commissioning.

The third project is the construction of a modest (10,000-class) clean room in the Coude' room of the Blanco. The plans and cost estimates for this project are underdeveloped, but the proposed room is not a very demanding project. The timescale for this project's completion is driven by the needs of another instrument (NEWFIRM) that is scheduled to arrive at CTIO in 2009. Therefore, the construction of the clean room should not represent a schedule risk to DES.

The fourth project is a study of the thermal environment of the four-meter dome. This part of the proposal has no formal budget, and the output of this study is a report. This is not a significant risk or cost item. However, this study's findings could lead to potential improvements that will enhance DES science by improving on the image quality at the Blanco telescope.

The fifth project is the installation of the utility and cooling lines that will be needed to support DECam at the Blanco PF. This program is not well-defined yet, as it is still dependent on the final choice of the cooling system, and the delivery of the components to CTIO. It is not a significant cost or schedule driver for the DES.

Effective integration of the TCS replacement project with DECam depends on the continued role of Tim Abbott as both head of the TCS project and Deputy Project Manager for DECam.

Integration of the system with the Blanco telescope is defined to be part of the installation and commissioning phase under the direction of CTIO, and therefore not part of the DECam project. While this is understandable from the point of view of the DECam project, this is a point of vulnerability for DES. The Memorandum of Understanding (MOU) and supporting documents need to be very clear about not just responsibilities and control, but costing procedures in case of problems at this stage.

3.3.2 Comments

The TCS replacement project is subject to schedule risks in part due to other potential commitments of the CTIO staff involved, and cost risks due to the conversion rate fluctuations. However, the schedule contingency in the project appears sufficient. As long as the project remains high priority within CTIO, the DES appears not to be at significant risk.

The connection between the TCS project and the DECam/SISPI component is explicitly made; however, the milestones identified are not tied to the DECam milestones, except by the participation of Tim Abbott.

If the TCS project slips significantly, there needs to be a formal mechanism for feeding this into the DECam development schedule. In particular, a document specifying the interlink between the milestones of the TCS project and DECam/SISPI milestones should be produced.

More detailed plans for the clean room should be developed soon (by the end of 2008), with the involvement of the DECam team and CTIO, as well as NOAO/NEWFIRM, to ensure that the cost of the project to CTIO is controlled.

3.3.3 Recommendations

1. Produce a document explicitly linking the TCS milestones that affect DECam/SISPI to the SISPI milestones so that there is no slippage risk in the schedules. This should be produced prior to January 2009.
2. Produce an analysis of the Blanco environment report, with the goal of identifying any improvements that can enhance the DES science return and impacts on the CTIO budget. This should be done as soon as the report is done, as any improvements could feed back into the error budget allowed for the other parts of DECam.

4. PLAN FOR COMMUNITY USE OF DES SYSTEMS, INSTALLATION, COMMISSIONING AND OPERATIONS

4.1 Findings

The Memorandum of Understanding (MOU) between Fermilab, NOAO, and NCSA represents a significant accomplishment toward ensuring that the DES System will be delivered as a facility instrument. This MOU defines the system deliverables to NOAO/CTIO for community use and defines the procedures for responsibility and control of DECam during installation, commissioning, and operation.

The MOU forward references several documents that are meant to specify implementation of agreements agreed upon. These documents are currently in various stages of completeness.

NOAO has led the development of a process to solicit input from the astronomical Community on their needs for using DECam. These needs are being used to define requirements for the DES System that fall outside those for DES itself. The requirements have been and continue to be incorporated into the DES system specifications as they develop.

The Committee was presented with a nominal installation plan and schedule. The committee thought that these plans were adequate for the current stage of the project. The commissioning and operations plans are in the preliminary stages of development and are presently at the conceptual design level. The Committee was presented with a straw man outline of the commissioning scope and schedule.

The Community Data Pipeline and its data products are a critical part of making the DEC System a facility instrument and fulfilling the community needs. Substantial progress was made toward the development of this pipeline and defining the output data products. The Committee was shown that existing software code comes close to meeting the current pipeline specifications.

4.2 Comments

The process of fully specifying the Community Data Pipeline is progressing well. The Committee was encouraged to see that processing dithered stacks is part of the baseline specifications, as well as processing individual images. Other special processing modes should

be identified based on common community use cases for the DECam System, with the goal of providing a final list of modes to be supported by the end of June 2008.

The Committee agreed that some of the performance specification for the quality of the data products was too loose. For example, the specifications state that the photometry derived from the pipeline should be accurate to ten percent. It is understood that this specification was driven to accommodate the wide range of possible photometric spectral bands that could be used by the community. In this particular instance the Committee judged that a relative specification would be more appropriate. For example the specification might read:

- Photometric accuracy/precision shall not be degraded by more than approximately one to two percent from the quality of the underlying reference data.
- This would yield better science productivity through increased performance that is tied directly to the quality of the reference data source.
- Other data products may be well suited to similar types of relative specification.

The scope as presented to the Committee of the DC5 tests on the Community Data Pipeline was not precisely defined. The specifications of these tests need to flow down from the requirements defined by the Community Needs document. This document is scheduled for completion by mid-2008.

As part of the Community Data pipeline the Committee would like to see the inclusion of specific data quality assessment products. Where appropriate these should be taken directly from those developed for the DES effort. Inclusion of data quality meta-data will improve the scientific return from the community use of DECam.

Even though the NOAO-led process for defining the community needs of the DES System has advanced well, the Committee was concerned by the limited audience that has reviewed the current draft of the Community Needs document. There is some risk that important requirements for the DES System may be overlooked thereby limiting the science capability available to the community. Several examples were discussed at the review stemming from narrow band imaging use cases, including:

- Altering the readout timing on the science sensors to lower the read out noise so that narrow band imaging is sky limited on long exposures.

- The design of DECam forces the guide sensors to use the same filter that is used for the science sensors. This will significantly reduce the number of suitable guide stars available when using narrow band filters. One possible solution to consider is using the hexapod to rotate DECam about the optical axis in order to increase the sky area available to the guide sensors. This would help mitigate the lower number of suitable guide stars seen through the narrow band filter. The project should investigate to what extent the current DECam design would support this use case.
- Another possible solution to the lower guide star flux in narrow band filters is altering the guide sensor integration time. The impact on telescope guiding performance should be evaluated.

The notional five-week commissioning period that was presented, three weeks followed by a two-week block, seems optimistic and less than optimum. The Committee agreed that an initial substantial block of time is necessary, given the high degree of first time integration occurring at CTIO. A subsequent series of evenly distributed shorter time blocks (e.g., four to seven nights) with ample time (e.g., approximately three weeks) for data evaluation and analysis and any adjustments that are implied, might be a better strategy.

The Committee recognized that the transition from the integration phase (on project) to the installation and commissioning phase (CTIO lead) is critical to the successful implementation of DECam. The Committee was not presented with a well-defined set of acceptance criteria that would be required for the hand off. These should be put in place as soon as possible since the hardware necessary for them would be part of the DECam project and will have to be budgeted and scheduled.

Because the forward reference documents in the MOU are still in progress, the specifics remain unclear. Thus what impact these may have on the DES System design could not be evaluated at the time of the review.

Included in the set of DECam deliverables are supporting documents covering user support, technical operation, and maintenance manuals. The Committee agreed that requirements for these documents need to be established well in advance of their delivery so that adequate time and resources are allocated for their production and review by NOAO/CTIO. These documents are mentioned in writing in the Project Execution Plan, but should also be explicitly shown in the deliverables table.

4.3 Recommendations

1. Consider making specifications for the Community Data Pipeline and its data products more stringent and link them to the quality of the underlying reference data where appropriate.
2. Produce an agreed upon document that explicitly defines the Community Data Pipeline deliverables, including its data products, by the beginning of 2009.
3. Develop a broad range of community derived use cases for the DES System prior to freezing the implied requirements and specifications for the DES System. Evaluate the need for additional requirements for the DES System.
4. Develop a set of technical acceptance criteria that defines the transition from integration to installation/commissioning phases on the Blanco telescope.
5. Develop a detailed installation plan based on the current DECam design. Use this plan to assess whether there are any design implications that need to be incorporated into DECam.

5. ENVIRONMENT, SAFETY and HEALTH

5.1 Findings

Fermilab has determined that the appropriate level of National Environmental Policy Act (NEPA) for the proposed action is a Categorical Exclusion (10CFR1021, Subpart B, Appendix B3.6). The DOE Fermi Site Office (FSO) approved the Categorical Exclusion on July 11, 2006 and no further NEPA review is required. The identification of the hazards associated with the project is documented in the November 6, 2007 DECam Preliminary Hazard Assessment Document. This document was approved by the DOE/FSO on November 16, 2007 and served as the basis for the preparation of January 14, 2008 DECam Preliminary Safety Assessment Document (PSAD) required for CD-2.

The review of the PSAD indicates that there will be minor or negligible impact from potential hazards on the health and safety of operating personnel and negligible impact on the health and safety of all other Fermilab personnel.

Any potential hazard will be mitigated by insuring that all operating personnel have received appropriate training and adherence to proper operational procedures. The DECam constructed has been assessed as a low hazard activity based on a systematic analysis of worst case accident scenarios involving risks that would exist if there were no engineered mitigation actions taken.

The DECam project subsystem managers are responsible for applying Integrated Safety Management (ISM) principles and functions for their subsystems in accordance with Fermilab Integrated ES&H Management Plan. The weekly manager meetings and the bi-weekly project meetings are the forums where managers raise safety issues related to the DECam project. When appropriate, advice on safety will be sought from the PPD safety committees. These committees will be asked to issue Operational Readiness Clearances (ORC), after appropriate review, for any new major equipment or facilities constructed by the DECam project. The Project ORCs are documented and collected in the project's document database. The DECam ES&H Coordinator plans and coordinates ES&H reviews of the project and the associated documentation.

5.2 Comments

Based upon the ES&H review of DECam project, it is concluded that construction of DECam will have minor or negligible impact from potential hazards on the health and safety of

operating personnel. It will have negligible impact on the health and safety of the public and the environment. The types of processes and materials used by the project at Fermilab are not new and are covered by existing Fermilab procedures and practices. Any potential hazard will be mitigated by insuring that all operating personnel have received appropriate training and adherence to proper operational procedures.

The ES&H documents on the DECam project were found to be in order at this stage of the project. However, the PSAD should be revised based on DOE/FSO and others' suggested comments. During construction and testing of the DECam project, the DOE/FSO will provide oversight of the project in accordance with the November 1, 2007 DOE/FSO ISM System Description.

5.3 Recommendation

1. Finalize and formally approve the DECam PSAD prior to start of the project construction.

6. COST

6.1 Findings

The DES management presented a DES baseline cost estimate of \$41.4 million (real-year dollars), which is made up of three separate projects:

- \$32.9 million DECam funded by DOE
- \$7.6 million DESDM NSF and other funding
- \$0.86 million CFIP

The DECam cost estimate can be compared to a CD-1 cost estimate of \$25.0 million. Cost increases from CD-1 include:

- Increased equipment costs (\$1.5 million)
- Incorporated university labor into TPC (\$1.1 million)
- Incorporated R&D from CD-0 into TPC (\$5.3 million)

The DECam estimate includes contingency of \$5.1 million (32 percent of remaining cost) on the MIE and \$500K R&D contingency. All costs are based in FY 2007 dollars, fully-burdened and include DOE/Fermilab out-year escalation. DECam installation and commissioning effort is not included in project and HEP base program supports Fermilab scientists.

DECam has requested a CD-3a to release approximately \$2.1 million for long-lead procurements. This would advance the CCD processing and packaging in the third quarter 2008 and the hexapod procurement in first quarter 2009.

The DESDM cost estimate is primarily a software project (heavy labor component) using a mix of funding sources. DESDM includes software testing and commissioning, but zero contingency.

CFIP costs are estimated at \$390K for equipment upgrades and \$470K for labor (\$860K total).

No contingency is included in the DESDM or CFIP portions, although the CTIO Director holds contingency for CFIP external to the project.

6.2 Comments

The DES management team is a capable group. The Committee appreciated the thorough presentations and frank discussion of the present status and the challenges that they see ahead. The cost and schedule estimates for the DECam, DESDM, and CFIP are developed as separate projects. An integrated project schedule will greatly improve overall project coordination.

DECam

The DECam resource-loaded WBS and schedule are well developed. Estimates are supported with a documented cost basis. DES appears to be adequately developed to support CD-2, however cost contingency appears too low particularly in integration, telescope simulator and activities in Chile. Cost estimates for CD-3a items (long-lead procurements) are adequate although some technical issues are unresolved. Approximately \$2 million of foreign procurements are exposed to currency risk. Strategies should be considered to mitigate risk.

DESDM

The DESDM resource-loaded WBS and schedule were presented based upon technical judgment. The estimate is primarily labor estimates supporting a software project. Distributed labor and partial FTEs will require strong management and coordination

CFIP

The CFIP cost and schedule estimate are not resource-loaded. This is primarily an upgrade to an operating facility.

6.3 Recommendations

1. Reevaluate and update the DECam cost and contingency estimates based upon recommendations in this report.
2. Reevaluate and update the DESDM cost estimates based upon recommendations in this report.
3. Recommend DECam for CD-2 after updating cost and contingency estimates.
4. Recommend DECam for CD-3a after satisfying earlier recommendations on CCD's and hexapods.

7. SCHEDULE and FUNDING

7.1 Findings

The DECam schedule is a logically-linked, resource-loaded schedule containing approximately 1,000 activities for delivery of the camera to CTIO. The critical path identified is driven by FY 2010 procurements (primarily filters, crate cooling system). A CD-4 milestone is identified in third quarter FY 2012. The overall schedule contingency is 12 months.

The DESDM has a resource-loaded schedule containing approximately 800 activities. The schedule is primarily labor-driven and follows a series of development cycles. Total DESDM development labor is approximately 44 years. The DESDM is complete with acceptance tests in fourth quarter FY 2011. The overall schedule contingency is approximately nine months.

The CFIP summary schedule was presented—roughly 12 months of schedule contingency is available. The DECam project presented a funding-constrained schedule based upon a bottoms-up resource-loaded schedule. Zero funding is planned for the final year of the project (FY 2012).

MS Project and COBRA (DECam) are the primary scheduling tools chosen to monitor schedule progress. Monthly Status and Earned Value Reporting have been in place for five months, and the DOE/Director's Earned Value Management System (EVMS) review concluded DECam was in compliance for self certification.

DESDM funding is provided via a proposal submitted to NSF for \$2.94 million to support the project scope. CFIP infrastructure improvements will be provided using operating funds. The funding profiles for each of the three subprojects are shown in the Table 7-1.

Table 7-1. DES Project Funding Profile								
WBS	Description	Costs through Dec07	Rem FY08	FY09	FY10	FY11	FY12	Total (AYK\$)
1.0	DECam	7,390	5,360	8,890	8,600	2,700	0	32,940
	R&D	7,390	3,690	610	0	0	0	11,690
	MIE		1,670	8,280	8,600	2,700	0	21,250
2.0	DESDM	2,339	813	1,340	1,431	1,713	0	7,636
	NSF	260	390	859	866	1,216	0	3,591
	FNAL (Scientific)	342	71	98	102	107	0	720
	UIUC (Astron + NCSA)	1,596	141	90	93	96	0	2,016
	In-kind Contributions	141	211	293	370	294	0	1,309
3.0	CFIP (Operating)	210	255	275	120	0	0	860
	TOTAL (AYK\$)	9,939	6,428	10,505	10,151	4,413	0	41,436

7.2 Comments

The Committee judged the schedule maturity for the DES projects to be at the appropriate level to support CD-2. Schedule contingency of 12 months (DECam) and nine months (DESDM) is considered adequate.

Schedule contingency is not costed. Any schedule delays will draw from contingency and should be estimated by the project for planning purposes.

Although the project has identified the primary project activities, overall integration should be improved. An integrated DES project schedule with identified subproject linkages will facilitate coordination of the entire DES project.

The DECam obligation profile is front-loaded and early use of contingency will need to be carefully managed. The long-lead procurements are important to help retire risk.

DECam project team should work closely with Fermilab to minimize potential continuing resolution effects on the project's procurement plans. Fermilab's Project Management Group can play an important role in informing laboratory management of any schedule or funding issues.

There is an effective use of milestones on all projects to monitor overall progress—commendable. Each project has identified the critical path activities and is actively managing schedule contingency. FTE estimates or manpower profiles provided for most areas of the DES project.

7.3 Recommendations

1. Develop an integrated DES project schedule that effectively connects the three projects.
2. Recommend DECam for CD-2 and CD-3a.

8. PROJECT MANAGEMENT

8.1 Findings

The DES project is made up of three major subprojects, the DECam project, the DESDM project, and the CFIP. A project director oversees the DES Collaboration and project that currently consists of 12 participating institutions and over 100 individual collaborators. The Office of High Energy Physics within DOE/SC funds the majority of the DECam project. Fermilab is the lead institution for DECam. The National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC) leads the Data Management project with NSF funding. The NOAO leads the CFIP with funding from the NSF as well. In-kind contributions and no-cost resources and deliverables form substantial and critical contributions in all three projects. In addition to the American collaborating institutions, there are three foreign consortia: United Kingdom-DES, Spain-DES, and Brazil-DES, each with specific in-kind deliverables. Additionally Spain-DES and the University College of London (UCL) have successfully applied for and received explicit funding from their respective funding agencies to participate in the DES project subject to U.S. funding agency approval of the project. In several instances, the in-kind or no cost contributions from collaborators include subcontracts to other institutions (for example University of Michigan subcontracts to Bonn University for the shutter) or vendors (UCL procures the optics from potential multiple suppliers).

A DES Council representing Fermilab, NCSA, and NOAO provides director level oversight of the project. H. Montgomery (Fermilab), R. Crutcher (NCSA), and T Boroson (NOAO) presently serve as its members. A final draft global MOU, known as *The Understanding*, was developed concerning the DES Council and its working relationship between the three principal institutions with latest revisions having been made shortly before this review (January 24, 2008). It should be ready for final signatures imminently.

Each of the DES collaborating institutions has a letter of application outlining its commitments and in-kind contributions to the DES project. The DES project has been actively transforming these letters of application into MOUs, and the majority of them have been signed with annually revised statements of work.

The governance of the DES project reflects its collaborative multi-institution and multi-agency aspects. The DES Management Committee represents the interests of the collaboration. The DES Project Director (J. Peoples) chairs this committee with members elected from the collaborating institutions and consortia with the DECam Project Manager (B. Flaugher), the DES

DM Project Leader (J. Mohr), and CTIO Director (A. Walker) participating as ex-officio members. The management committee addresses collaboration management and overall DES project coordination.

The DES project has a Science Committee that is tasked with providing the survey science requirements to the DES project as a whole. A Community Needs Working Group was established to review and integrate community needs into the three projects. It is the forum for the integration of the community pipeline into the NOAO/DPP E2E system and the DECam use of the NOAO DTS.

Each of the major projects within the DES project (DECam, DESDM, and CFIP) have project managers and project offices commensurate with their relative size.

The DECam project is the largest of the three. It has added a 50 percent Project Scientist with systems and scientific requirements responsibility since the May 2007 DOE/NSF review. The project scientist joins the project manager and two deputies that previously formed the DECam Project Office. One of the two deputies is a member of the CTIO staff and serves both as the principal CTIO contact for DECam and is responsible for integration and testing plans and execution of DECam at CTIO. The DECam project has six Level 2 Managers each responsible for specific major subsystems or activities within the DECam project.

The DESDM project has a project director, project manager, and five WBS Level 2 activities. The CFIP is organized within the CTIO as its collection of projects drawing upon the existing operating budget of CTIO for funding and CTIO staff for resources.

The highest level of integrating systems support within the DES project is provided by the DES Project Director and an executive committee constituted by the project offices of the three projects that meets on an approximately monthly basis.

The DES project and the DECam project in particular (with regard to DOE requirements) fully responded to eight of the nine management recommendations from the May 2007 DOE/NSF review with recommendation on systems and integration support at the DES project level still being examined.

Part of the charge of this review was to assess the readiness of the DECam project to receive CD-2/3a, (Approve Performance Baseline and Long Lead Procurement). The specific areas within DECam seeking long lead procurement approval include WBS 1.2 CCD Processing, WBS 1.2 & 1.3 CCD Packaging, and WBS 1.5 Hexapod procurement.

The DECam project presented a complete and adequate set of project documentation necessary as part of establishing the project baseline and receiving CD-2. Appendix F summarizes the lines of inquiry (LOI) that were pursued as part of this review. The DECam project responses to all 17 LOI were deemed satisfactory with only four LOI having any additional comment. These four were risk management, start-up test plan, system functions and requirements, and the Integrated Project Team.

8.2 Comments

The DECam project has adequately prepared all the requirements necessary to meet the requirements for CD-2/3a. The Committee judged that the documentation presented by the DECam project as required by the External Independent Review (EIR) summary assessment and the LOIs were satisfactory and adequate for DOE to approve CD-2/3a for the DECam project (see Appendix F). The Committee endorses DOE approval of CD-2 for the DECam project once the cost and contingency baselines have been reevaluated and revised (as necessary) for the telescope simulator activities and tests, DECam integration and assembly tasks, all tasks and activities at CTIO, and incorporated a detailed estimate of travel paid by the DECam project vs. operating or base funding (cf. §3.1.3.3 and §6). The Committee endorsed DOE approval of CD-3a, long-lead procurement authorization for the CCD production (cf. §3.1.2). The Committee also endorsed CD-3a for the front end electronics AIN production once a design review and noise tests have been completed of the AINv2.1 (cf. §3.1.3.3). The Committee endorsed CD-3a and procurement of the hexapod assembly once a finite element modal analysis of DECam mounted in the telescope top ring needed to validate the design of the cage, vanes, and hexapod is completed (cf. §3.1.1).

The DESDM and CFIP projects presented their project execution plans (PEP). The Committee judged these to be adequate initial plans. The DESDM project has a good project team in place and acknowledges that their proposed project baseline is not consistent with the scope of work activities anticipated. The Committee specifically identified areas where DESDM management can strengthen the effort as detailed in Section 3.2. The DESDM baseline change control thresholds and protocols as contained within its PEP (Section 4.9.2) appeared to be inconsistent with respect to management levels and schedule delays. Additionally, the schedule delays are not referenced to either explicit level milestones or tasks.

Integration of the three individual projects within DES remains an area where additional effort will bring substantial benefit to the collaboration. Milestones, schedules, and risk and

issues management should be carefully synchronized and integrated so as to minimize delays or increased costs stemming from inadequate coordination.

The Understanding (MOU) is a very comprehensive and strong document. It should be signed as soon as possible while understanding that revisions will likely be inevitable. Of necessity for keeping a tractably sized document, *The Understanding* references many subsidiary documents. Most of these documents do not yet exist or are only in preliminary draft form. An explicit schedule should be developed for the subsidiary documents referred to within *the Understanding*.

Only a general statement of support by Fermilab to the DECam installation after CD-4 is included in *The Understanding*. This creates some concerns and uncertainties. It is true that support for operations and commissioning have generally been forthcoming on other projects, and the Committee judged that Fermilab will certainly support DECam installation and commissioning activities after CD-4. Nonetheless, an explicit declaration of the minimum level of support that DES can anticipate from Fermilab would mitigate uncertainties for both CTIO and DES.

Recent restructuring and budget uncertainties within the United Kingdom Science and Technology Facilities Council (STFC) resulted in a complete reprioritization process of funding in the UK. This prioritization process has left the status of UK funding for the DECam optics polishing in question. The DOE, NSF, and DES project should work together to minimize and mitigate this particular risk.

The DES project and the DECam project in particular have worked and improved configuration, systems, and integration management since the May 2007 DOE/NSF review. DECam has developed several documents, and management plans connected within this area including an initial draft DECam systems configuration list and interface summary currently under development. While a great improvement, the addition of a 50 percent project scientist is not sufficient to address all the configuration, systems, and integration issues and risks facing DECam or DES. These areas are weak at this time and need to be strengthened within DES and DECam. Failure to address these deficiencies will increase risk of unrecoverable cost increases and schedule delays. Examples of items that are lacking or only in most preliminary nascent state are configuration controls, requirement flow downs and traceability, and error budgets and trees.

Risk and risk management were areas of concern for the committee. The DES project showed a cognizance of many of the risks associated with the project as a whole. DECam has written a risk management plan and developed an initial risk register. Likewise DESDM and

CFIP have shown awareness of risks associated with their respective projects. All of this is good as far as it goes, but the Committee was concerned that it is not nearly adequate enough. The DECam risk registry does not include any summary or integrating risks and is not used as a management tool to drive behavior or attention within the project. Risk and issues logs routinely discussed, reviewed, updated and acted upon are simply not used at present. There is no explicit effort at the DES project level of highlighting, tracking, and addressing mitigation strategies for risks and issues. The DES project, DECam, DES DM, and CFIP should individually and collectively develop and implement risk and issue management approaches that are used on a day-to-day management basis. A conscious, concerted effort in this area will reap benefits in a series of projects that execute more smoothly and predictably and integrate more easily.

In the area of risk management and mitigation, the DES Collaboration needs to look at mitigating risks during operation and science data taking, as well as during the project execution phase. The optical filters are one example of an area where operational risk reduction can be done at the present time. When soliciting quotations from the potential filter manufacturers, options to procure additional spare filters at the time of the initial order should be requested. Additional filters purchased at the same time as the initial set of filters will likely cost only a fraction of what the initial filter set will cost. The filters will be removed and exchanged during the course of operations and will have a real risk of being damaged or broken. Having operational spares purchased at the time of the procurement of the initial set will significantly reduce the down time or data acquisition interruption during operations.

Another risk mitigation strategy that has been mentioned previously in this report (cf. §3.1.2) is accelerating the CCD production rate. The major risk here is the *non-statistical* incidents that could disrupt production or result in the loss of complete or substantial fractions of lots of wafers/chips. The DECam project should allocate additional funding for the CCD manufacturing in order to accelerate the production rate to that approaching the maximum that the facilities (LBNL/DALSA) can handle. The limit on the production rate should be the capacity of LBNL/DALSA and not a funding limit. *The DECam project should do this accelerated CCD manufacturing rate even if it results in the slowing of other activities within the DECam project to accommodate the revised funding allocation.* CCD production was identified as one of the major critical risk areas of the DECam project and moving to a configuration where it is capacity limited rather than production limited has several benefits. It retires early the risk on the CCDs. It will provide additional schedule buffer or insurance. It will likely reduce costs as it will increase efficiency and yield and learning curve benefits in processing will be realized.

The DES Project Director continues to do a remarkable job in assembling an enthusiastic collaboration and bringing a diverse set of complementary capabilities with significant in-kind

contributions together. The DES Collaboration is an enthusiastic competent team and the Project Director's direct efforts have greatly increased the likelihood of success of the overall effort and reduced the overall risk.

8.3 Recommendations

1. Proceed with obtaining CD-2 for DECam project once recommended cost/schedule modifications have been incorporated into the project baseline.
2. Proceed with obtaining CD-3a for DECam project, consistent with the recommendations in section 3.1.
3. Implement active explicit risk/issues management on a day-to-day basis across the DES project (DECam, DESDM, CFIP) before the next DOE/NSF review.
4. Provide additional explicit configuration, integration/systems effort within DES and DECam before the next DOE/NSF review.
5. Codify an explicit minimum level of support the DES can anticipate from Fermilab for DECam installation post CD-4 before the next DOE/NSF review.

APPENDIX A

**CHARGE TO THE
COMMITTEE**

U.S. Department of Energy
and the
National Science Foundation

November 15, 2007

To: Mr. Daniel Lehman, Director, DOE Office of Project Assessment, SC-28

Subject: Request to Review the Dark Energy Survey project

The Department of Energy (DOE) Office of High Energy Physics (OHEP) and the National Science Foundation (NSF) request that you conduct a review of the preliminary design of the entire Dark Energy Survey (DES) project on January 29 – 31, 2008 at Fermi National Accelerator Laboratory (FNAL).

The DES experiment plans to utilize the existing Blanco Telescope at the Cerro Tololo Inter American Observatory (CTIO) in Chile to study the nature of dark energy. The project includes the fabrication of a new camera (DECam) optimized for the study of dark energy, the CTIO facilities improvement project (CFIP) for upgrade to the telescope and CTIO facility, and a data management system (DESDM). The DES project plan calls for funding for the DECam to be provided by DOE and funding for the DESDM and CFIP from NSF. Funding for CFIP would be provided through the NOAO, CTIO's parent organization. In addition, funds are being requested from other U.S. and foreign institutions.

For DOE, this review will serve to assess the project's readiness to establish the technical, cost, and schedule baseline of the Dark Energy Camera (DECam). For NSF, the review will serve to assess the progress and status of the proposed CFIP and DESDM. The validation of the DECam baseline is needed for Critical Decision 2, Approval of Performance Baseline. In addition, OHEP is planning to seek CD-3a (Approve Limited Fabrication) so that the DECam may begin long lead procurements and a limited set of other fabrication activities that are needed to maintain the proposed schedule with adequate contingency. Please review the necessity of and the project's readiness to carry out these activities.

In carrying out its charge, the review committee is requested to consider the following questions for all parts of the project:

1. Technical: Does the technical design and associated implementation approach for each part of the experiment satisfy the scientific and technical performance requirements?
2. Cost: Is the cost estimate complete, well documented, and credible? Is the contingency adequate for the risk?
3. Schedule: Is the proposed schedule reasonable and appropriate in view of the technical tasks and projected funding profiles?
4. Management: Is the management structure adequate to deliver the proposed technical scope within specifications, budget and schedule?

5. Limited Fabrication: Are the requested long-lead procurements and other fabrication activities scheduled as part of CD-3a necessary to achieve the stated schedule? Have the necessary preparations to execute these activities?
6. Are the environmental, safety and health (ES&H) aspects being properly addressed given the project's current stage of development?
7. Documentation: Is the DECam documentation required by DOE Order 413.3A for CD-2 and CD-3a complete? Does the project satisfy all 16 lines-of-inquiry specified in DOE O 413.3A (see Appendix A)?

Kathleen Turner is the DOE program manager for the Dark Energy Survey and will serve as the Office of High Energy Physics contact for the review. Nigel Sharp of the NSF Division of Astronomical Sciences will serve as the NSF contact for the review.

We appreciate your assistance in this matter. As you know, these reviews play an important role in our programs. Both agencies look forward to receiving the committee's report, within 60 days of the review.

/s/

Wayne Van Citters
Director
Division of Astronomical Sciences
National Science Foundation
Arlington, VA
Germantown, MD

/s/

Dennis Kovar
Associate Director
for High Energy Physics
Office of Science
Department of Energy

APPENDIX B

REVIEW

PARTICIPANTS

**Department of Energy/National Science Foundation Review of the
Dark Energy Survey (DES) Project**

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Daniel R. Lehman, DOE/SC, Chair

Review Committee

Andy Albrecht, UC Davis
Julian Borrill, NERSC
Bryan Butler, NRAO
Rob Cameron, SLAC
Pepin Carolan, DOE/FSO
Chuck Claver, NOAO
Ian Dell'antonio, Brown U.
Sat Goel, DOE/SC
Alex Grillo, UCSC
Matt Johns, Carnegie Inst.
Robert Lupton, Princeton U.
Paul Padley, Rice University
Mark Reichanadter, SLAC
George Ricker, MIT
Kem Robinson, LBNL
Roger Smith, CalTech
Nick Suntzeff, TAMU

Observers

Mike Procario, DOE/SC
Kathy Turner, DOE/SC
Paul Philp, DOE/CH
Nigel Sharp, NSF
Tom Barnes, NSF

APPENDIX C

REVIEW

AGENDA

**Department of Energy/National Science Foundation Review of the
Dark Energy Survey (DES) Project**

AGENDA

Tuesday, January 29, 2008—Comitium, WH2SE

8:00 am	DOE Executive Session	D. Lehman
9:00 am	Welcome/Laboratory Overview— One West, WH1W	H. Montgomery
9:15 am	DES Overview – Science Intro, DES Org, MOU Structure	J. Peoples
9:55 am	DECam Technical Requirements/Comparison of.....	D. DePoy
	DECam/DES to Other Projects	
10:25 am	BREAK	
10:40 am	DECam Overview Including Integration at CTIO.....	B. Flaugher
11:15 am	DES/DM Overview and Requirements.....	J. Mohr
11:45 am	Roles of NOAO.....	A. Walker
12:15 pm	LUNCH	

Parallel Plenary Presentations

	<i>DECam—One West, WH1W</i>	
1:15 pm	DECam Project Mechanics (MOUs, Config. Control, Doc. Summ.)	W. Merritt
1:30 pm	CCDs	T. Diehl
1:50 pm	Front End Electronics	T. Shaw
2:10 pm	Survey Image System Process Integration (SISPI).....	J. Thaler
2:25 pm	Opto-Mechanical System.....	A. Stefanik
2:45 pm	Integration	B. Flaugher
	<i>DES Data Management System—Hornets Nest, WH8X</i>	
1:15 pm	Cost, Schedule.....	C. Beldica
1:40 pm	Archive.....	D. Cai
2:00 pm	Pipeline Processing Framework.....	G. Daues
2:20 pm	Astronomy Processing	J. Mohr
2:40 pm	Photometric Calibration	D. Tucker
3:00 pm	BREAK	
3:15 pm	Breakout Sessions	
	<i>DECam</i>	
	CCDs— SiDet	T. Diehl/J. Estrada
	Front End Electronics/SISPI— Black Hole, WH2NW	T. Shaw/J. Thaler
	Opto-Mechanical/Optics— Snake Pit, WH2NE	A. Stefanik/P. Doel
	<i>Status DESDM Development—Hornets Nest, WH8X</i>	J. Mohr
	DECam Simulations Program	
	DESDM Data Challenges	
	DESDM Requirements and Technical Specifications Overview	
4:45 pm	DOE Executive Session	
6:00 pm	Adjourn	

Wednesday, January 30, 2008

- 8:00 am Breakout Sessions
DECam
CCDs—**RaceTrack, WH7X**..... T. Diehl/J. Estrada
Front End Electronics/SISPI—**Black Hole, WH2NW** T. Shaw/J. Thaler
Opto-Mechanical/Optics—**Snake Pit, WH2NE** A. Stefanik/P. Doel
Cost, Schedule, and Management—**Comitium, WH2SE**.....B. Flaughner
Data Management
Current Issues/View toward Operations-**One North, WH1NW** J. Mohr
11:00 am Data Management-Cost, Schedule and Mgmt—**Comitium, WH2SE**..C. Beldica
CFIP
CFIP Tech. Details, Cost/Sched.—**Hornets Nest, WH8X** T. Abbott
of the Telescope Control System
12:00 pm LUNCH
1:00 pm *DES Mgmt Session*
DECam as a Community Instrument—**Comitium, WH2SE**
Community Data Management, incl. Community Pipeline req..... C. Smith
Community Pipeline Implementation Plan..... J. Mohr
Installation, Commissioning and Operations Arrangement..... A. Walker
Management Questions/Discussion (starting at 2:30)
DES/FNAL/NCSA/NOAO MOU
Institutional MOU
Answer questions from the Committee from the previous day
3:00 pm DOE Executive Session—**Comitium, WH2SE**

Thursday, January 31, 2008

- 8:00 am Committee Working Session
9:30 am Executive Session Dry Run—**Comitium, WH2SE**
12:00 pm Lunch
1:00 pm Closeout Briefing with DES Management—**Curia II, WH2SW**
2:00 pm Adjourn

APPENDIX D

COST, SCHEDULE
and
FUNDING TABLES

Cost and Schedule

The CD-1 DOE Total Project Cost (TPC) range was \$24.1 - \$26.7M for the DECam Project.

DOE TPC presented at this Review was \$32.9M, including 32% contingency on Major Item of Equipment (MIE) funds.

In addition, in-kind contributions to the DECam Project are estimated at \$6.5M.

Revisions to the DOE TPC were:

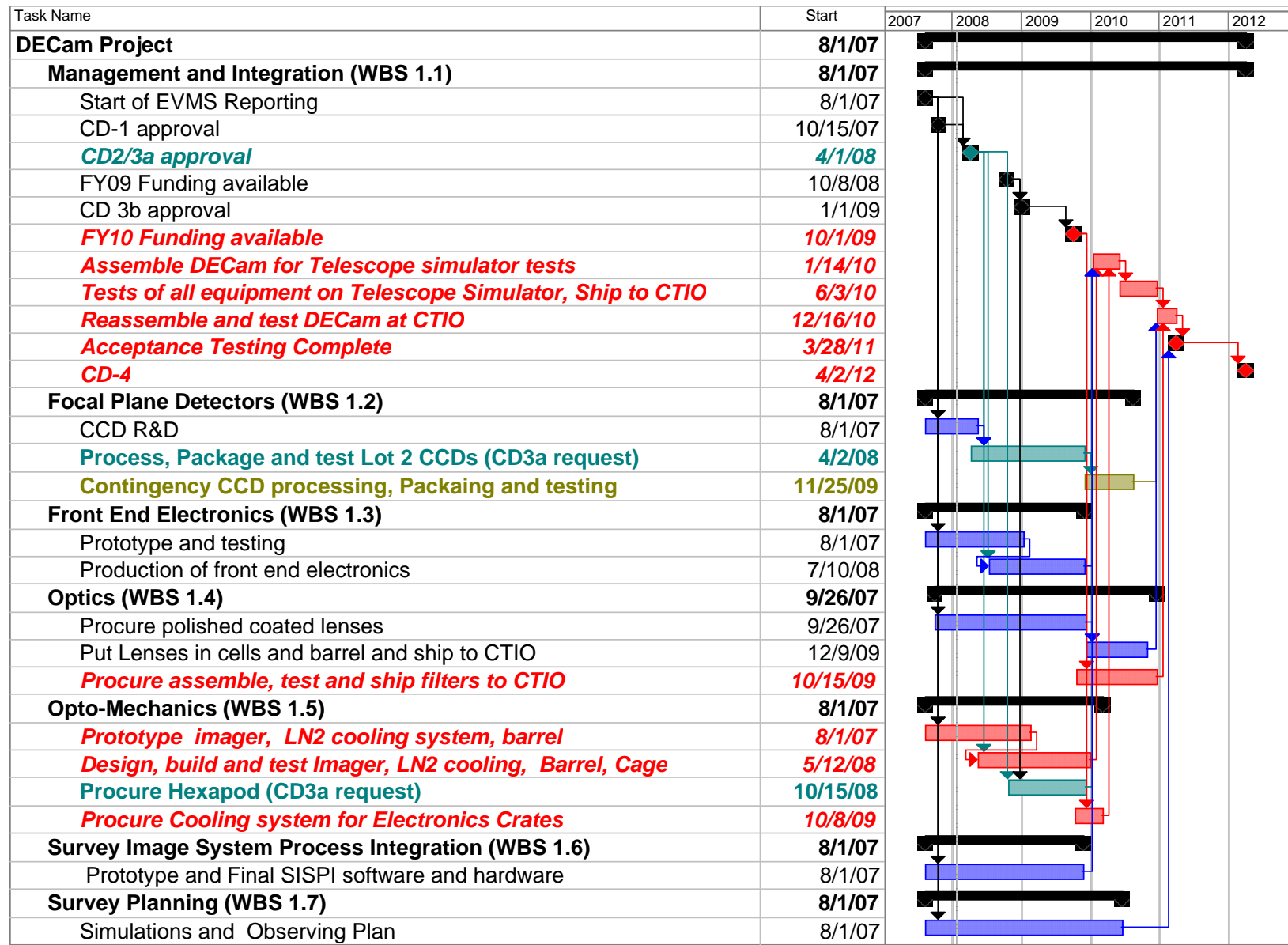
- Technical cost increases since May CD-1 Review: \$1.5M
- DOE funded University Base Grants (UIUC): \$1.1M
- R&D from CD-0 to August 1, 2007: \$5.3M

DECam Project Funding Profile:

	FY06	FY07	FY08	FY09	FY10	FY11	Total
R&D (FNAL/DOE)	2.1	4.6	3.8	0.6	0.0	0.0	11.1
MIE (FNAL/DOE)		0.0	1.7	8.1	8.4	2.5	20.7
UIUC Base Grant	0.2	0.2	0.2	0.2	0.2	0.2	1.1
Total	2.3	4.8	5.7	8.9	8.6	2.7	32.9
Integral	2.3	7.0	12.7	21.6	30.2	32.9	

*UIUC Base Grant will be incorporated into the R&D and MIE lines

DECam Schedule Summary



Milestones

Proposed/actual Critical Decision (CD) Milestones:

Milestone	Description	Baseline Date
0.0	CD-0: Approve Mission Need (Ground-Based Dark Energy Experiment)	November 22, 2005
0.1	CD-1: Approve Alternative Selection and Cost Range	October 10, 2007
0.2	CD-2: Approve Performance Baseline	2nd Qtr. FY 2008
0.3a	CD-3a: Approve Limited Construction	2nd Qtr. FY 2008
0.3	CD-3b: Approve Start of Full Construction	1st Qtr. FY 2009
0.4	CD-4: Approve Project Completion	3rd Qtr. FY 2012

CD-3a approval is being requested for long-lead procurements of: charge coupled device (CCD) processing and packaging and hexapod procurement.

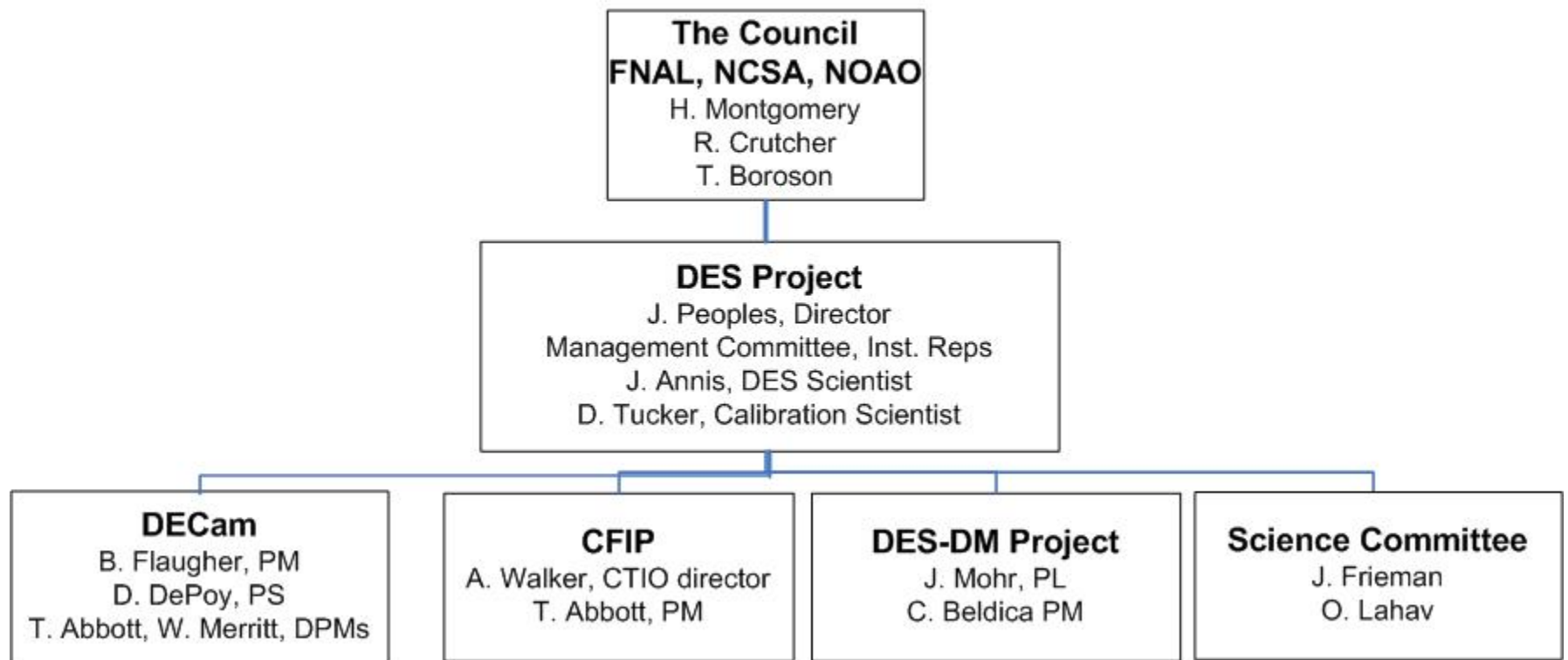
APPENDIX E

MANAGEMENT

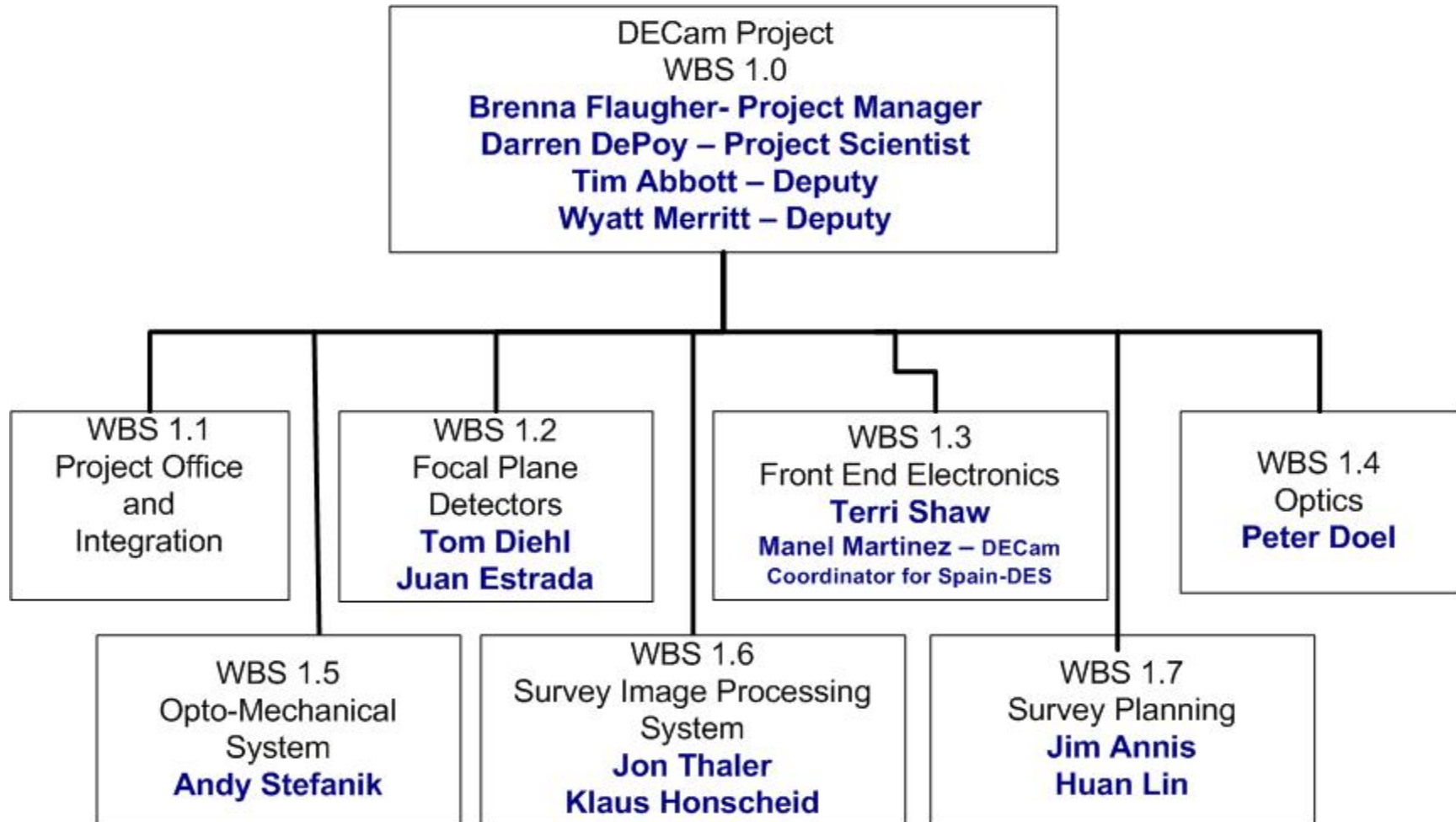
CHART

DES Organization—A Collaboration Perspective

Dark Energy Survey Projects



DECam Project Level 2 Managers



APPENDIX F

EIR LINES of INQUIRY

EIR Summary Assessment of the DES/DECam Project Performance Baseline

EIR Element	SC Review Team Assessment	Comment
1. Work Breakdown Structure	Satisfactory	<p>Project Response: The WBS is developed to a level of detail appropriate for each individual subsystem. Typically it goes to level 4 or 5. The WBS dictionary has been developed and detailed basis of estimate documentation has been prepared where appropriate. The notes field of each task with M&S or Labor cost over \$10k and all the milestones contain a description of the scope of the task, equipment and/or labor basis of estimate. There is a column in the schedule file called BOE which contains the document number in the DES document data base for the basis of estimate information or it indicates that the relevant information is contained in the notes field. There is also a column called BOE hyperlink which contains a link directly to the BOE documents.</p> <p>Committee Response: Committee concurs.</p>
2. Project Cost and Resource Loaded Schedule	Satisfactory	<p>Project Response: A Resource Loaded Schedule for FY07-FY12 has been developed using Microsoft Project. Level 2 managers and Cost Account Managers are identified in the MSP file. The cost basis for the TPC is currently a combination of responses from vendors, engineering estimates and estimates from previous experience building prototypes or similar projects. The notes field in the MSP file contains the basis of estimate for each task with M&S or Labor cost over \$10k as well as many of the smaller tasks. A WBS dictionary produced from the MSP file contains a printout of the entire schedule, including the notes field and the resources on each task; this information is provided in PDF format along with the MSP file.</p> <p>The deliverables and the definition of project completion are described in the DECam Project Execution Plan. Specific expected performance parameters for the DECam Project are contained in the DECam Technical Specifications and Requirements document and in the DECam Project Technical Design Report.</p> <p>The Resource Loaded Schedule is matched to the funding profile provided by FNAL.</p> <p>Committee Response: Committee concurs, with updates to cost estimate as recommended in the report.</p>

EIR Element	SC Review Team Assessment	Comment
3. Key Project Cost and Schedule Assumptions	Satisfactory	<p>Project Response: The CD-2/3a review is scheduled for Jan. 29th. For our planning purposes we have assumed that the CD2/3a approval will be granted on April 1st, 2008. We are requesting CD3a approval at the Jan. 29th review for the CCD processing, the CCD packaging and testing and for the Hexapod. These are all long lead time and early procurements will reduce the schedule risk to the project.</p> <p>We are estimating that the CD3b review will be in July or August and the full CD3 approval would be granted on Jan.1, 2009. Following DOE-OHEP guidance, scientist effort on the project is entered into the schedule file and tracked at zero cost. Technical labor and procurements are costed resources. Earned Value and monthly reporting started on August 1st, 2007, 2 months prior to CD1 approval.</p> <p>The project also provided an estimate of the cost of the R&D specific to the DECam project that occurred between CD-0 and CD-1 as well as an estimate of the cost of engineering supported by the DOE University base grant. Only UIUC is supporting technical labor from their base grant. This will be included in the project TPC. CD-0 Approval for a Ground-Based Dark Energy Experiment was approved on November 22, 2005. Overhead rates are provided by the Fermilab accounting office. The escalation rates come from the annual guidance from DOE-OHEP for the Laboratory's budget submission. The MSP file contains the direct costs for M&S and Labor. The escalation rates and overhead are applied by the COBRA program.</p> <p>A contingency factor is set by the L2 managers on each task based on the guidance:</p> <ul style="list-style-type: none"> - 10% - similar devices fabricated and tested - 20% - have not yet completed fabrication and proved that it works - 30% - have a design and experience with similar devices and/or initial vendor discussions but no quote - 40% - have a design but no vendor input and/or little experience with similar devices - 50% - complete guess or large variation in vendor quotes <p>The CCDs receive special treatment:</p> <ul style="list-style-type: none"> - The base schedule includes 6 Lots of CCDs (2A-F). This will provide 126 wafers minus breakage. With our current estimate of the yield 100 wafers = 106 ± 28 good devices. - An additional lot is included in the cost contingency to cover a yield as low as 15%. - The processing, packaging and testing of the contingency lot would occur in FY10 so the contingency is placed in this year. The tasks are in the schedule to keep track of the schedule impact. - Schedule risk due to low CCD yield is mitigated by the ability to install CCDs at CTIO. <p>The contingency factors were reviewed by project management and updated to reflect recent vendor responses to requests for information and requests for quotes. This analysis produced a 32% contingency on the MIE which is reflected in the TPC. The Baseline Schedule includes 12 months (33%) of schedule contingency.</p> <p>Committee Response: Committee concurs, with updates to contingency assessment as recommended in the report.</p>

EIR Element	SC Review Team Assessment	Comment
4. Critical Path	Satisfactory	<p>Project Response: The Critical Path (tasks with 0 total slack) for the project is currently driven by funding constraints in FY08 and FY09 which push procurement of the major systems (filters, cooling for the FEE crates) into FY10. The next closest tasks to the critical path (Design and test of the LN2 cooling system) have roughly 3 weeks of slack. These tasks are on schedule and are technically driven. The schedule durations are integrated in to the MSP schedule file and are based on engineering estimates and vendor quotes and on experience with the design and fabrication of prototypes.</p> <p>Committee Response: Committee concurs.</p>
5. Risk Management	Satisfactory, with comment	<p>Project Response: The DECam Risk Management Plan exists and is in active use. It includes documentation, analysis, and mitigation. Risks have been identified and classified according to a combination of likelihood and impact. Mitigation plans have been developed down to WBS Level 3 for all moderate or high risks and status is continuously tracked. The Risk Registry and the risk mitigation forms are maintained in the Document data base, organized by WBS L2 area. Only the production of fully tested CCDs and the fabrication of the lenses are classified as high risk. These risks have been substantially mitigated by the R&D program for the CCDs, and initiation of early procurement of the lenses, although they are still considered high risk.</p> <p>Overall project risk has been mitigated by choosing technologies and solutions that have already been demonstrated or only require modest development to meet the DECam requirements.</p> <p>Committee Response: Committee acknowledges that a satisfactory risk management plan has been written. Aggressive risk and issue management must be instituted within the day-to-day management of the project and fully integrated into the schedule updates and status, cost and contingency analysis. Likewise global and cross cutting risks are not identified within the risk register. The risk register documents risks but needs to be adopted as an active management tool and be fully integrated and implemented for all activities, especially at the systems level.</p>
6. Funding Profile	Satisfactory	<p>Project Response: The funding profile is consistent with the resource loaded schedule.</p> <p>Committee Response: Committee concurs.</p>
7. Project Controls/EVMS	Satisfactory	<p>Project Response: The project control and EVMS systems are developed in compliance with the Fermilab policy and using standard Fermilab practices and tools. Earned value tracking, and variance reports are in use. Monthly reports have been prepared starting Aug. 2007. These contain the Cost Performance Reports which indicate earned value. The Fermilab Director and the DOE Site office held a joint review of the EVMS system in use for DECam. The overall conclusion of the review was "The DECam project has satisfactorily implemented the bulk of the elements required for a 'self-certified' EVMS".</p> <p>Committee Response: Committee concurs.</p>

EIR Element	SC Review Team Assessment	Comment
8. Basis of Design	Satisfactory	<p>Project Response: The DECam project maintains a Technical Requirements and Specifications document which provides the design basis for all of the DECam subsystems and DECam as a whole. The DECam design is well developed and this is documented in the Technical Design Report. Several areas of work which are based on previous R&D are ready for production (CCD Processing and Packaging). Several Make vs Buy comparisons have resulted in decisions to buy complete systems rather than devote engineering resources to their design and fabrication. System requirements have been identified, and are consistent with the specifications and preliminary drawings. The major mechanical systems have individual Requirements and Specifications Documents which are actively maintained and used to communicate design details between subsystems, or for procurement of complete systems from a vendor. The major software systems have Interface Control Documents.</p> <p>Committee Response: Committee concurs.</p>
9. Design Review	Satisfactory	<p>Project Response: Since receiving CD-0 approval, the DECam Project as a whole has been reviewed 5 times:</p> <ol style="list-style-type: none"> 1) Fermilab Director's CD-1 Review July 2006 2) Joint DOE/NSF review of DES and CD-1 Review of the DECam Project in May 2007 3) Preliminary CD2/3a Director's Review of DECam Oct. 2007. 4) CD2/3a Directors' Review of DES Dec. 11-13, 2007 5) Fermilab and DOE EVMS review of DECam Dec. 18-19 2007 <p>The review reports and the project responses are part of review materials for each subsequent review. In addition, 5 reviews of subsystem designs were convened by the DECam Project manager in the past year and additional reviews are scheduled throughout the project. These reviews are a necessary step before initiation of major procurements and design cycles. Safety reviews for systems commissioned as part of CCD R&D have been conducted by the appropriate ES&H committees in PPD.</p> <p>Committee Response: Committee concurs.</p>

EIR Element	SC Review Team Assessment	Comment
10. System Functions and Requirements	Satisfactory with comment	<p>Project Response: System functions and requirements flow down from the DES Science objectives and are captured in the DECam Technical Requirements and Specification Document. This document is prepared and maintained by the DECam Project scientist. The requirements and specifications are consistent with the key performance parameters and the deliverables described in the Project Execution Plan and with the mission need. The DECam Technical Requirements and Specification Document will be used to define the detailed technical tests that ensure that the delivered DECam meets the requirements. Each major mechanical system has a specifications and design document which include references to drawings that serve as the mechanical interface control. The major software systems have functional requirements documents and interface control documents. The design requirements are reflected in the baseline, including safety aspects.</p> <p>The Mission Need for the project is contained in the CD-0 Approval for Ground-Based Dark Energy Experiment that was approved on November 22, 2005. To lay out a roadmap for studying the nature of dark energy, the High Energy Physics Advisory Panel (HEPAP) and Astronomy and Astrophysics Advisory Committee (AAAC) commissioned a subpanel, the Dark Energy Task Force (DETF).</p> <p>In their spring 2006 report, the DETF recommended a mix of experiments with independent and complementary measurements to address the nature of dark energy. The report defined a four-stage program to understand the nature of dark energy, with Stage III being mid-term projects and Stage IV being longer term, next generation, projects. They defined a figure of merit (FOM) based on the errors in measurements of dark energy quantities. Using this FOM, they concluded that, given uncertainties in projected systematic errors, no single method of measuring dark energy could robustly constrain both parameters. Rather, they concluded that tight constraints would need to come from multiple dark energy methods.</p> <p>DES will measure the dark energy parameters with the four dark energy methods recommended by the DETF and will provide improvement in the FOM between a factor of 4 and 5 over current (Stage II) projects. Thus the DES satisfies the DETF recommendations for a mid-term (Stage III) project.</p> <p>In a letter dated June 23, 2006, HEPAP's P5 prioritization subpanel recommended that DOE and NSF jointly pursue the DES project, which can provide significant advances in our knowledge of dark energy.</p> <p>Committee Response: Committee concurs. Configuration management should be strengthened within the DECam project as error budget, requirement and specification flow downs and traceability are only nascent or missing.</p>
11. Sustainability	Satisfactory	<p>Project Response: The DECam project does not involve building any new facilities at Fermilab or elsewhere. The camera will be installed on a 4-m telescope in Chile which is operated by NOAO (CTIO) and funded by NSF.</p> <p>Committee Response: Committee concurs.</p>

EIR Element	SC Review Team Assessment	Comment
12. Hazards Analysis	Satisfactory	<p>Project Response: A Preliminary Hazard Assessment was made as part of the CD-1 preparations, and subsequently updated. Based on this assessment, a Preliminary Safety Assessment Document has been written to describe the mitigations of these hazards. The PHA has been signed and forms part of the approved CD-1 documentation. The PSAD has been reviewed by the PPD ES&H liaison.</p> <p>Committee Response: Committee concurs.</p>
13. Value Management/Engineering	Satisfactory	<p>Project Response: Value Management/Engineering is fundamental to the execution of the project and is described in our Technical Design Report. The value engineering processes that led to the current design choices for the CCDs, the Front End Electronics and optical design are described. In addition, detailed value engineering documents describe the optimization of the CCD thickness and the placement of electronic components in the readout chain. The design of the cooling system has undergone detailed technical reviews as part of the value engineering process and finalization of the design.</p> <p>Committee Response: Committee concurs.</p>
14. Start-up Test Plan	Satisfactory with comment	<p>Project Response: The DECam Project Scientist is responsible for developing the testing plans which will be performed prior to shipping to Chile and again prior to installation on the telescope. It is linked to the CD-4 deliverables identified in the PEP. It identifies the acceptance and operational system tests required to demonstrate design performance and safety requirements. Cost and schedule durations for these tests are appropriately incorporated into the baseline. A testing plan has been drafted and is now under document control in the document database.</p> <p>Committee Response: Committee concurs. The present test plan is only a framework draft and will require significant development in successive revisions before it is a comprehensive and complete document.</p>
15. Project Execution Plan	Satisfactory	<p>Project Response: The Project Execution Plan reflects and supports the way the project is being managed. It has been updated from the CD-1 Preliminary PEP with the new funding profile and the resulting schedule. It is consistent with other project documents and establishes a plan for successful execution of the project.</p> <p>Committee Response: Committee concurs.</p>
16. Acquisition Strategy	Satisfactory	<p>Project Response: The Acquisition Strategy is consistent with the way the project is being executed. No significant changes in acquisition approach have occurred since its signature by the AE for CD-1 in October 2007. It still represents the best value to the government.</p> <p>Committee Response: Committee concurs.</p>
17. Integrated Project Team	Satisfactory with comment	<p>Project Response: The IPT has been formed and meets monthly or as needed. It is chaired by the Federal Project Director. The charter as well as the full membership is incorporated into the PEP.</p> <p>Committee Response: Committee concurs. The IPT presently lists the Fermi Site Office Manager as a member of the IPT. This is not necessary as the Federal Project Director represents the FSO Manager.</p>